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Rio San Diego Irrigation Project,

State of Coahuila, Republic of Mexico

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RIO SAN DIEGO IRRIGATION PROJECT, STATE OF COAHUILA, REPUBLIC OF MEXICO

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BY

THEODORE SPERRY ABBOTT
B. S., UNIVERSITY OF ILLINOIS, 1877

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE

DEGREE OF

CIVIL ENGINEER

IN

THE GRADUATE SCHOOL

OF THE

UNIVERSITY OF ILLINOIS

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U N I V E R S I T Y O F I L L I N O I S

THE GRADUATE SCHOOL

April 1, 1911

I hereby recommend that the thesis prepared under my personal supervision by THEODORE SPERRY ABBOTT entitled RIO SAN DIEGO IRRIGATION PROJECT, STATE OF COAHUILA, REPUBLIC OF MEXICO, be accepted as fulfilling this part of the requirements for the degree of CIVIL ENGINEER.

Ira O. Baker

Head of Department.

Recommendation concurred in:

Frederick M. Mann

A N Talbot

COMMITTEE ON FINAL EXAMINATION.

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I N T R O D U C T I O N.

In this paper I have attempted briefly to describe the climatic and topographical conditions, conditions of land-ownership, and governmental interventions, -- all leading to the necessity of irrigation work on the Mitchell basin.

My [illegible] of [illegible], work which was completed several years ago, a sufficient time [illegible] to note results and also to find out what seems to be the most serious [illegible] to a satisfactory realization of the [illegible] desires of those who invested his capital and put his faith in the land.

CENTRAL PLATEAU OF MEXICO.

The Central Plateau of Mexico extends from the northern extremity of the Republic, southward practically the entire length of the Rocky Mountain system, the northern part lying within the States of Coahuila, Chihuahua, Durango, and Zacatecas. It is diversified by isolated mountain ranges whose general trend is from northwest to southeast. The valleys lying between these ranges are usually very narrow (from two to ten miles in width) or of considerable uniform elevation, and connected by low mountain passes. A general longitudinal section of the Plateau would give an elevation of 4,000 feet at El Paso, 5,000 feet at Chihuahua, 3,500 feet at the Laguna de las Rio Nazas, and 6,000 feet at San Luis Potosi.

Along the eastern margin the water shed trends to the Rio Grande and thence to the Gulf of Mexico. The descent is very abrupt, the water courses are narrow and rocky, and are dry during the greater part of the year but in the rainy season they become veritable torrents. The central valleys are in most instances cut off from the eastern drainage. During the rainy season lakes are formed in the depressions which, before the annual rainy period returns, are usually dry. The annual rainfall varies greatly; the rains are exceedingly local in their character, frequently falling upon narrow belts of land only, not more than a mile or two in width. Twelve inches of precipitation is a good average for the year, although at times in certain localities there has been no rain at all for more than two years, while in August, 1900, 20 inches fell in four days at Monterrey. In Torreon, about 100 miles west of Monterrey, the entire precipitation for that year did not exceed

four inches. The principal rainfall occurs in July and August, the amount falling during these months is about 75 per cent of the total annual amount.

Where no reclamation work has been done, the table lands are for the greater part arid deserts, the brief springtime life which succeeds the rains being quickly followed by dull grey monotony. The mountain sides glistening in the heat are naked, save for a scanty covering of spines and thorns. In the valleys the grasses soon dry, become brittle, and are blown before the wind. Other plants that seem to thrive in these surroundings have been found to be of great value. The most important are the guayule (rubber shrub), the maguey and lechuguilla (fiber plants), and candelilla. The eastern edge of the table lands and the limiting mountains are deeply eroded because of the heavy rainfall in a brief time and of the steep inclination of the water courses. The detritus is carried down to the near coastwise levels where the rich valley lands of Northern Mexico are found.

In the northern part of Coahuila, the central plateau is indented by a range of mountains following a south easterly course, beginning in Texas as the Chisos Range it terminates in Coahuila where it is known as the Sierra Mountain. To the south of these mountains -- between them and the Rio Grande -- lie some of the most fertile lands of Northern Mexico.

The World Irrigation Bank seeks to utilize the rainfall proceeding from these mountains for the irrigation of the valleys at their base from the project of this Bank.

CONDITIONS OF OWNERSHIP AND LABOR.

During the Spanish regime many small colonies were formed, generally about a spring or along a stream of flowing water. To the colonists there was given -- by the Crown of Spain -- a certain area of land (10,000 to 20,000 acres) about the village, of which the tillable lands was proportioned out to the early settlers according to their needs, the remaining lands being held in common. This to a great extent is the state of affairs in the municipalities existing to-day. Some of the more enterprising have purchased from their less fortunate brethren, and all the families have some representation in the general weal. The main canal is held in common; but the water privilege is divided into hourly equivalents corresponding to each day of the week, -- in some cases the days are divided into hours. Every property owner has the right to the entire flow of the canal upon the day or days that by custom accord are allotted to him and "use only" in the event disposal of his water rights. Especial arrangements are made for the months of 31 days. The cleaning and repairing of the canal are subject to municipal control. Outside of the villages the land is generally held in large estates -- more so in the arid regions.

Twenty thousand acres is considered a small property, many exceed one million. The reason for this is that the proportion of valuable tillable land is so small compared with the total area that even large tracts have but a few acres of "pan llevar" (bread raising lands). The large tracts are usually grants, some procured from the Crown of Spain and intended to foster colonization. Others were practically seized by the Mexican Government to some ex-

trail or public man in consideration of valuable services rendered to this country.

The State of Coahuila comprises 40,000,000 acres of land of which there is not more than 300,000 acres under cultivation, the remainder being devoted to stock raising. Twenty acres of the average dry land of the northern part of Mexico is barely sufficient to raise a head of stock. One half of the State is practically worthless for any purpose whatsoever, some of the large tracts being practically in little better condition than when ceded by Spain two hundred years ago. One reason for maintaining lands in large tracts under one ownership is that the rainfall is hardly sufficient to raise a crop, and therefore irrigation must be resorted to, and the cost of canals, dams, and reservoirs is far beyond the means of the small land owner.

In recent years the Federal Government has aided in reclamation work by the granting of a subsidy based upon the number of hectares of land reclaimed. So far this has been done only in the case of large estates. Labor upon the haciendas is performed by tenants who live upon the place, some work as renters, receiving two thirds of the crop if they bear all the expenses of production, or one half after expenses are deducted -- if they receive aid from the owners. When employed as day laborers they usually receive from 37 to 50 cents per day in silver, equivalent to $18\frac{3}{4}$ to 25 cents per day United States currency. Whenever possible work is allotted by task -- a certain amount being equivalent to a day's labor.

According to the Law, schools for primary instruction must be maintained upon the haciendas, this however is frequently more honored in the breach than the observance, the result being that the

proportion of illiterates is great. According to the census of 1900, out of a total population in the State of Coahuila of 290,000, 212,000 can neither read nor write, and this State is considered one of the more advanced in rudimentary instruction.

GOVERNMENT OWNERSHIP OF WATER.

On account of the limited and usually undependable rainfall and the consequent necessity of utilizing all the water possible -- either by the use of storage reservoirs or by diversion dams, as in the case of running water, -- the Federal Government has assumed ownership over practically all the water courses of the republic, -- those that have water for a few days in the year only, as well as those of a constant supply, -- so that one may be owner of the land upon which the rain falls or through which the stream may run and still have no right to impound the rain water or divert the stream for irrigation or industrial purposes, unless by the process of law the right be granted by the Government, the object being to control the use of the water by law, to provide that it be properly used and that no one receive more than is necessary for the extent of tillable land he may have susceptible of irrigation.

That there is a great deal of water wasted by improper or imperfect irrigation -- especially during the night -- there can be no doubt; but still there has been a step taken in the right direction and the ultimate result will be that no part of the rainfall within the arid region of Mexico -- where it can be utilized for irrigation -- will be allowed to find its way to the sea. The most thorough control of a water supply by the Government is shown in the case of the Nazas river which is dry during nine months of the year but has a normal flow of 45,000 cubic feet per second in flood time. This stream irrigates 200,000 acres of cotton lands in the States of Coahuila and Durango. The Federal Government has appointed a Commission whose duty it is to see that owners of a water right

have their just proportion of the exceedingly valuable flood water. Intake gates are opened, raised, lowered, or shut in accordance with the orders issued by the Commission, based upon readings of water gauges conveniently located.

To secure a right to divert water for irrigation from any of the water courses within the jurisdiction of the Federal Government a petition must be presented to the Secretary of the Public Works in which is set forth:

(a) The stream from which the water is to be taken.

(b) Quantity required per second.

(c) Location, extent, and quality of lands to be irrigated.

(d) Nature of crops to be raised.

(e) If the stream is a permanent one, the amount of its flow to be given.

(f) If water is only available at flood time, an approximate gauge to be given.

(g) Any other information that might be considered as necessary to satisfy the Secretary that the water is required and can be properly utilized.

(h) A map showing the general situation must accompany the petition.

The petition must be published in the official Federal and State papers, and a period of 60 days is set for the filing of any opposition from parties who may claim prior rights to the water in question. The opposing parties must present the necessary proof in support of their claims, the validity of which will be settled by the Courts.

Upon granting the petition, a reasonable time is given to present detailed plans of dams, intakes, canals, reservoirs, etc., and a date is set for beginning and finishing the work. Upon approval of the plans an inspector is appointed by the Government to see that the work is carried out in accordance with these plans. A deposit must be made with the Department in bonds of the public debt (the amount of which depends upon the magnitude of the undertaking) to guarantee the fulfilment of the obligations upon the part of the petitioner. The latter -- upon commencing the construction -- gives, in addition, freedom from taxation for five years, free importation -- for one only -- of all materials, implements, tools, etc., used in the construction of the works or the cultivation of the property, the right to expropriate private property for the construction of canals, reservoirs, or any other works necessary for the development of the project, the amount of damages to be settled by a Judge of the Federal Court.

The detailed plans which must be presented to the Department for approval before construction can begin, must contain:

1. The meander of the stream from which the water is to be taken, for a distance of one kilometer above and an equal distance below the intake.

2. Longitudinal profile of the axis of the stream showing stage of the water -- if any.

3. Cross sections of the stream, approximately 200 meters distant one from the other. They must cover the entire portion of the stream meandered and extend at least 200 meters beyond the bank on either side.

4. Map and profile of the location of the canal. Upon the profile, and corresponding to every station is written the elevation of the ground, grade, the cut or fill, and the alignment. The stations are 20 meters in length.

5. Near the intake a reference point must be established, if possible its exact elevation above sea level must be determined, and

When this can not be done its approximate elevation is taken by a barometer -- generally an aneroid. Its direction and distance from the zero point of the canal location is noted. All levels are referred to the elevation of this point.

6. Cross sections of the canal at various points are taken, showing the surface of the water when the canal is running at its proper complement of water as determined by the concession.

7. Detailed plans of all works such as dams, intakes, retaining walls, aqueducts, piers and road bridges.

The descriptive report which accompanies the maps must give the formulas and calculations showing that the various works have the requisite strength for the object intended, and that the canal will carry no more water than the amount ceded in the concession. For the determination of the dimensions of the section of the canal and of the intake the formulas and coefficients of Kutter and Ganguillet are used.

After the plans, presented in duplicate, are approved by the Department, work may begin under the vigilance of the Government Inspector. When the work is finished according to the plans and within the specified time, and certified by the Inspector, the Government extends the title to the water according to the terms of the concession.

[illegible] PROJECTS.

In the above described manner a portion was diverted to the Federal Government Solitaire #1 well, a point at the mouth of the Rio Grande (approximately 6,000 litres per second) for the irrigation of a tract of arable land in the valley of the Rio Grande lying within the State of Coahuila. Surveys and plans were made and the work executed under the direction of the writer.

SOURCE OF WATER SUPPLY.

The San Diego river is the only available stream whose waters are permanent and more or less uniform throughout the year and at the same time available for the project under consideration. It is formed by the confluence of the two water courses -- Loop and Arboles. These proceed from the Burro Mountains and flow southward, and have a gravel bed and are dry on the surface nearly all the year; but beneath there is a strong undercurrent flowing, which at the Cabaceras breaks out in several large springs, the source of the San Diego river.

These water courses above their confluence are about 60 kilometers in length each, and form a drainage area of 240 square kilometers. The intake is just below the confluence. At this point the flow at low water was -- when the survey was made in 1902 -- about 2 cubic meters per second. During floods the river rises 7 to 8 meters, and the flow is 3,000 cubic meters per second. Below this intake there had previously been ceded water rights for the village of Jimenez and other points, to the amount of about 2 cubic meters per second, consequently the canal and other works were constructed to receive 5,000 liters per second.

The population of the Burro mountains is about 1,200 persons above the intake in this district country. The rainfall for several years, of which data, were about 60 centimeters per annum. During the season immediately preceding the surveys, this precipitation -- which, taken consideration the limited drainage area -- would hardly be sufficient to produce the recorded flow in the river, from which it is inferred that the underground current that supply the river from

water from sources outside the drainage area and not noticeable from the surface.

In recent years -- and since these works were constructed -- there has been a gradual diminishing of the flow of all streams throughout northern Mexico. The normal flow in the Rio Grande does not exceed 6 cubic meters per second; consequently the average flow in the canal during last year did not exceed 3 cubic meters of water per second over and above previous water rights. From the records of the rain gauge kept at Del Rio, across the river from Las Vacas, a remarkable decrease in precipitation is noted:

PRECIPITATION AT DEL RIO.

Year.	Precipitation.
1906	27 inches
1907	22 "
1908	18 "
1909	15 "
1910	10 "

In the Burro Mountains the precipitation greatly exceeds this; but there are no records showing the exact amount.

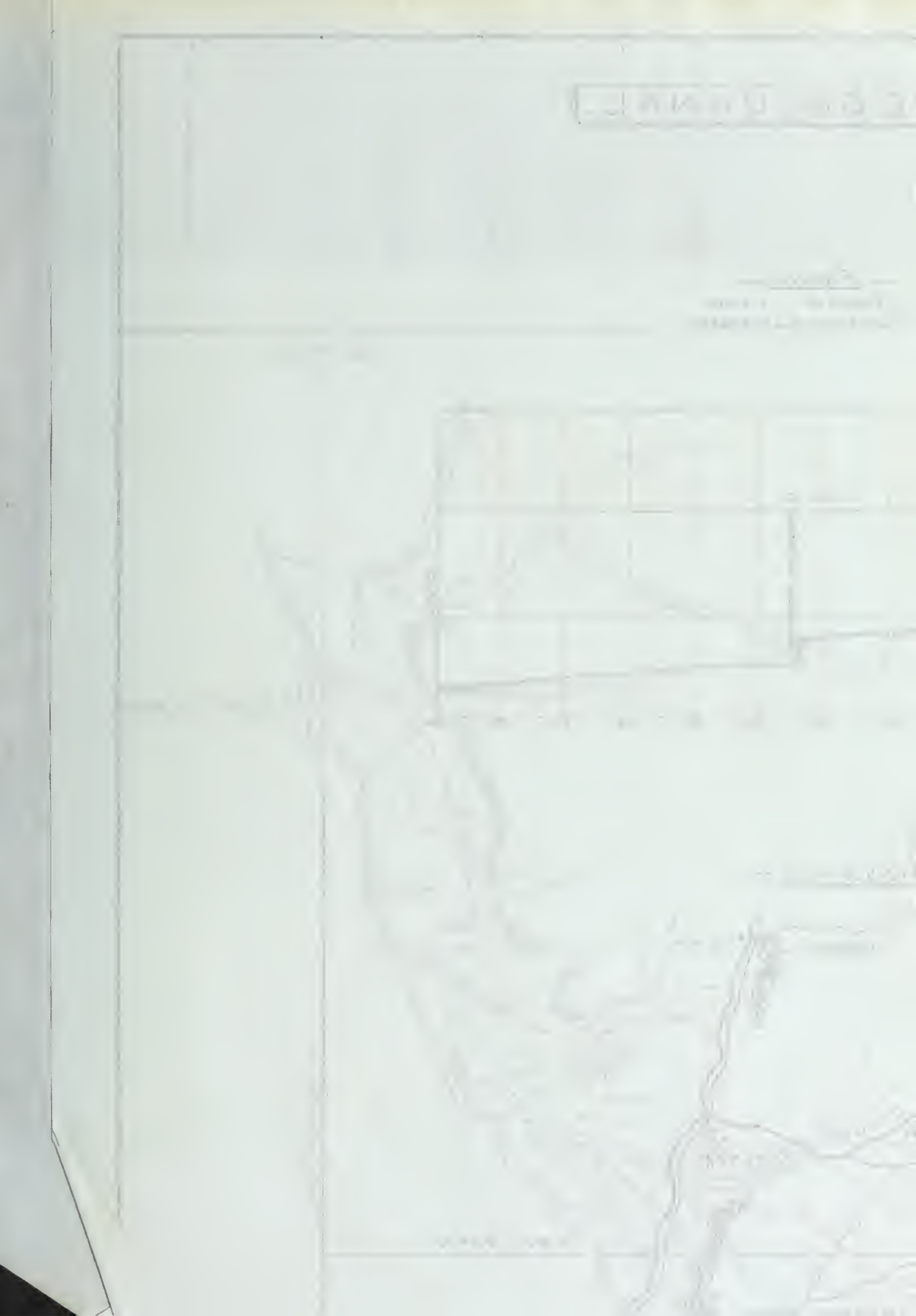
THE RECONNOISSANCE.

The original idea of the promoters of this enterprise was to make use of the waters of the San Diego river for the irrigation of the rich alluvial lands of the Rio Grande Valley lying to the south of the Arroyo Blanco and between Coral and Ciudad Porfirio Diaz. From previous knowledge of the country and with all information obtainable, the following plan was decided upon:

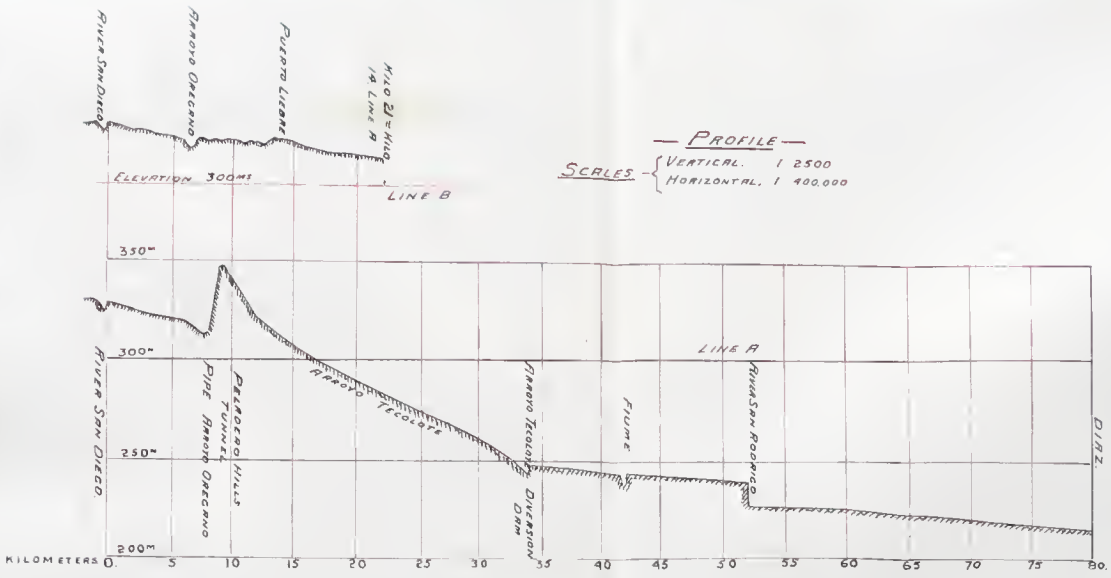
To divert the waters of the San Diego river to the head of the Tecolote Arroyo and use this arroyo as a canal to a point near the lands to be irrigated, then by a diversion dam turn the water into a canal just north of the Arroyo Blanco, cross this on a flume and begin the irrigation of the lands to the south, continue the canal southward and allow the water to fall into the San Rodrigo river and then by a diversion dam and a canal bring the water to the main body of land to the south of Coral. PLATE I shows the general plan.

In accordance with this idea the reconnoissance began at Diaz and continued up the Rio Grande Valley toward Coral, traversing 4,000 hectares of superior tillable land, thickly covered with mesquite. Two branches of the Arroyo Blanco were crossed, requiring flumes of 100 meters in length. A point on the San Rodrigo river -- whose altitude is sufficient to command the lands to the south -- was found a short distance above the Hacienda, 27 kilometers above Diaz. The minimum grade of the canal was fixed at 40 centimeters per kilometer.

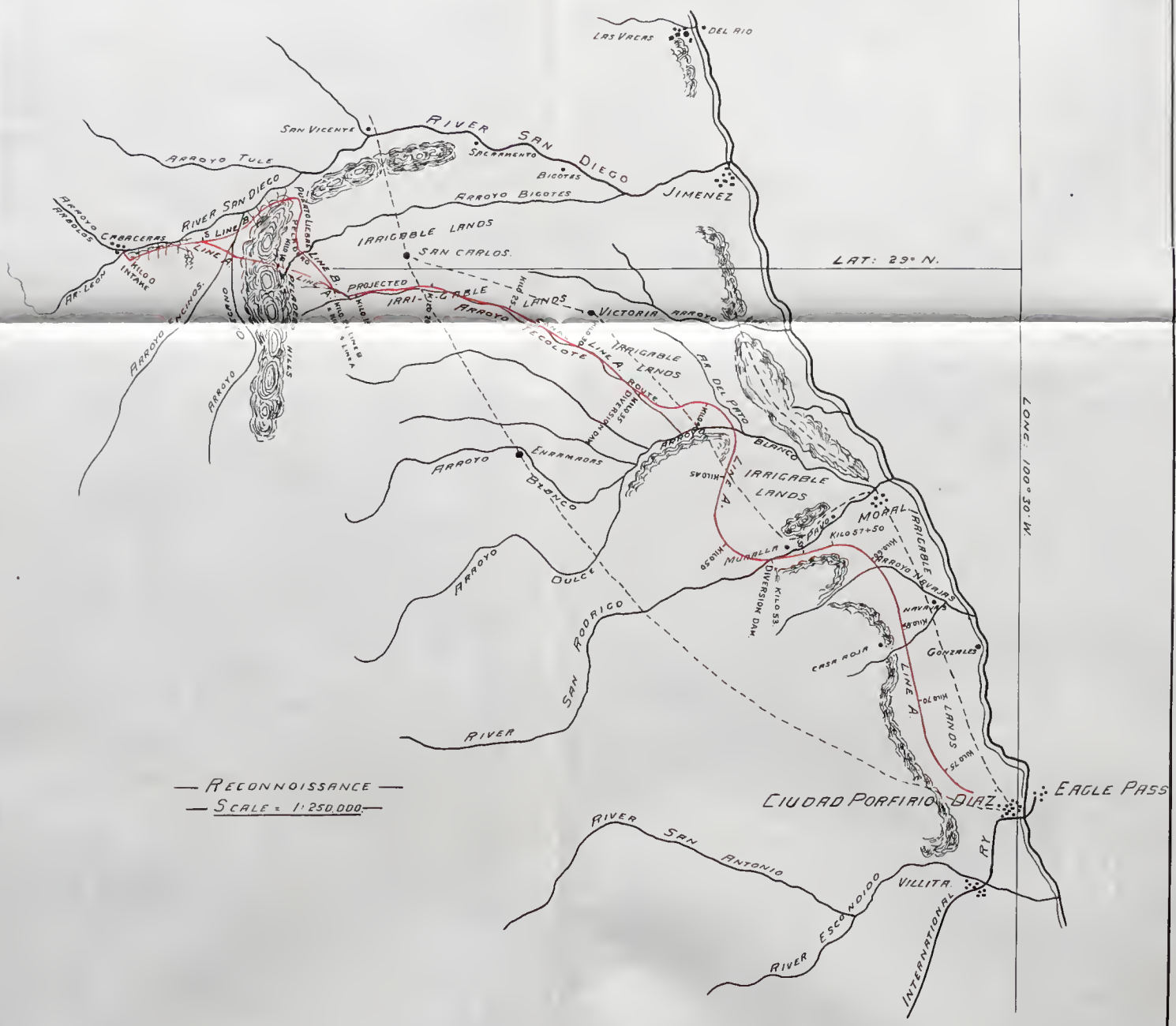
The San Rodrigo river is a stream 200 meters in width at the point of crossing, and during the dry season the flow is scanty



SAN DIEGO CANAL.



— THE RECONNOISSANCE —



— RECONNOISSANCE —
— SCALE = 1:250,000 —

PLATE I.

and all appropriated to owners of the property along the stream. In flood times the water rises 2 meters above its bed, and the flow is 4,000 cubic meters per second. The bed where the canal would cross is gravel; and the foundation for a dam 11 m deep. The water coming from the north, after falling into the river, may be conducted to the canal by a low diversion dam of brush placed on a gravel bed. This dam will probably be washed away each year during the annual freshets and must be replaced, which is cheaper than an expensive permanent structure, and will serve the purpose.

From the Macelle the line continues northwest, traversing the arable lands to the south of the Arroyo Blanco and crossing this stream by a flume 200 meters in length, enters the valley lands of the Arroyo Tecolote. The point for diverting the water from the Tecolote Arroyo was found 7 kilometers from the crossing of the Arroyo Blanco at Kilometer 35. From this point to Diaz there are 6,000 hectares of rich valley land susceptible of irrigation. From the diversion dam in the Tecolote to Peladero no canal will be needed -- the channel of the Tecolote will serve as the canal.

To this point there is no question about the route, it is apparent upon inspection, and it is marked Line A on PLATE I.

From the Peladero -- head of the Tecolote valley -- to a point on the San Diego river, whose altitude is sufficient to divert the waters of the river to the Tecolote, there are two possible routes:

Line A continued, passing under the Peladero hills by a tunnel, and

Line B, by Dieiro Pass.

From the intake to Kilometer 0 these routes are identical.

At this point they separate, uniting again in the Tecolote Arroyo. As Line B is the longer it will enter the arroyo somewhat below Line A.

The diversion dam in the San Diego river will be 80 meters long and one and one half meters high. The foundation will be solid rock.

To kilometer 5 -- where the two lines diverge -- the country is rolling and rocky traversed by several small water courses. Below kilometer 5, Line A will cross the Encinas and Oregano Arroyos on a flume 1,000 meters long, passing this the line enters a tunnel 2,000 meters in length with heavy cutting at each approach. Passing the eastern approach to the tunnel the country is not difficult and the line enters a tributary to the Tecolote at kilometer 14. Line B crosses the Oregano at kilometer 7, and follows along the west and north sides of the Peludero Hills, crossing the Libre pass At kilometer 15, and entering the Tecolote Arroyo at kilometer 21; from thence to the irrigable lands the two lines are identical.

From the Libre Pass to the Oregano the line crosses many sharp gullies along the hill side, requiring bridges and retaining walls. The ground slopes at right angles to the line and is very rough, consequently in order to get the desired depth on the lower side of the canal the cutting on the upper side will be heavy. The ground is porous and to avoid loss by filtration the canal must be lined throughout four kilometers of its length.

ESTIMATES OF COST.

I have prepared approximate estimates of the costs of Lines A and B, and in addition I give a comparative summary at the end from which it will be seen at a glance which is the cheaper. In both of the estimates I have adopted the following units of work and unit prices in Mexican currency.

AMOUNT OF EARTH WORK. With the adopted grade and the required flow, the canal will have a width of 4 meters at the base; slope ½ vertical to 1 horizontal, depth 1.5 meters; making a normal area of 7.125 square meters or a normal cutting of 7,125 cubic meters per kilometer.

COST OF EXCAVATION. Earth, 20 cents per cubic meter; loose rock, 50; and solid rock, $1.25 per cubic meter.

BRIDGING. The flume will have a width of 3 meters and a depth of 1.5 meters; it will be of cypress, 6 centimeters in thickness. It will rest upon 8 pine stringers 30 centimeters deep by 15 centimeters wide, and 5 meters between supports. The posts, braces, and floor beams will also be of pine. The total weight of the bridge and water will be 25,000 kilogrammes. The supports between will be masonry piers, 5 meters long by an average of 80 centimeters in width. The lumber that enters into one span will be equivalent to 800 feet B. M. of cypress and 1,300 feet B. M. of pine.

The cypress will cost delivered on the ground $90.00 per M. The pine, $70.00 per M. The cost of construction will be $15.00 per M. Iron tie-rods and nails will cost $10.00 per span. We have then the cost of one span of flume as follows:

800 feet of cypress at . . .	$90.00	$ 72.00
1,300 " " pine at	$70.00	$ 91.00
Labor on 2,100 feet of lumber at	$15.00 .	$ 31.50
Rods, nails, etc.		$ 10.00
Total cost of a 5 meter span		$204.00
" " per lineal meter		$ 41.00

MASONRY. The masonry is estimated at $8.00 per cubic meter.

TUNNEL. The section of the tunnel will be 3.00 meters by 2.00 meters. The rock is not hard. I estimate the cost of the tunnel at $40.00 per lineal meter. In order to work as many headings as possible, shafts will be sunk varying in depth from 10 to 30 meters. I estimate 150 lineal meters of shafts at $20.00 per lineal meter. The section of the shaft will be 2 meters square.

DIVERSION DAM. The unit prices are as follows:

Concrete masonry	$16.00	per cubic meter
Other masonry	$10.00	-do-
Solid excavation in water .	$ 3.00	-do-

ESTIMATE OF COST, LINE A.

EARTH WORK.

Section 1. Kilometer 0 to Kilometer 5.

For a short distance below the intake the cutting will be about 6 meters in depth; the average depth of the canal in this section will be two meters. The material will be one half solid rock and one half loose rock.

25,000 cubic meters solid rock at $1.25 . . $31,250.00

25,000 cubic meters loose rock at $0.50 . . 12,500.00

Total for section 1 . . . . $43,750.00

Section 2. Kilometer 5 to Kilometer 6.5

The material is soft, mostly earth and the cross section normal.

10,000 cubic meters of material at 25 cents per cubic meter . . . . . $ 2,500.00

Section 4. From Kilometer 7.5, east end of flume, to Kilometer 9, West portal of tunnel.

The country gradually rises to the west portal of the tunnel, where the cutting will be 9 meters in depth. The material is mixed; one is about one half earth, one fourth loose rock, and one fourth solid rock. This makes the average cost of a cubic meter about 54 cents. The area of a 9 meter section, 1/2 to 1 slopes is 76.5 square meters, this, at 54 cents per cubic meter will make the cost of one lineal meter of open canal $41.27, approximately the estimated cost of one lineal meter of the tunnel. I estimate 24,000 cubic meters of material in this section.

25,000 cubic meters earth
at 20 cents $5,000.00

12,500 cubic meters loose rock
at 50 cents $6,250.00

12,500 cubic meters solid rock
at $1.25 . . . . . $15,625.00

Total $26,875.00

Section 5. Kilometer 9 to Kilometer 11.

This section is 2 kilometers of tunnel. Include 160 meters of masonry for portals and a little lining at the entrance.

2,000 lineal meters of tunnel at
$10.00 per lineal meter $20,000.00

150 lineal meters of shaft at
$20.00 per meter . . . . . $ 3,000.00

160 cubic meters of masonry at
$8.00 per cubic meter . . . . . $ 1,280.00

Total $24,280.00

Section 6. Kilometer 11 to Kilometer 12.

The excavation is solid rock and will average 3 meters in depth.

10,500 cubic meters of rock at $1.25 . . . $20,625.00

Section 7. Kilometer 12 to Kilometer 14.

The country is slightly rolling, and the material is three-fourths earth and one fourth to be rock. The average cutting is 3 meters.

15,000 cubic meters of earth
at 20 cents $3,000.00

5,000 cubic meters of loose rock
at 50 cents $2,500.00

Total $5,500.00

Section 8. From the Diversion Dam in the Arroyo Tecolote to Kilometer 52.7.

In this section the material is nearly all earth and the depth of the canal will be 1.30 meters. There will be 1,000 cubic meters of solid rock at the diversion dam at kilometer 75. As some water will now be taken from the canal for irrigation the section will be reduced.

1,000 cubic meters of solid rock at $1.25	$ 1,250.00
100,000 cubic meters of earth at 20 cents	$20,000.00
Total	$21,250.00

Section 9. From the Diversion Dam at the Rio San Domingo to Kilometer 57.5.

Coming out of the San Diego river the cutting will be deep for at least one kilometer, averaging 4 metres. The material will be gravel. The side slopes of the canal will be 1 to 1. The entire wetted section throughout this kilometer must be lined with concrete of gravel and cement to prevent filtration. The lining will be 10 centimetres in thickness. The rest of the section is normal. The material is earth.

20,000 cubic meters of earth at 20 cents	$ 4,000.00
40,000 cubic meters of gravel at 20 cents	$ 8,000.00
1,000 lineal meters of lining at $12.00	$12,000.00
Total	$24,000.00

Section 10.

At kilometer 57.5 the canal enters the principal body of irrigable lands. The main canal will be divided into laterals and small ditches. For this work I estimate a cost of $15,000.00

Grouping the costs of the sections already detailed we have the following for the cost of the earthwork.

Section 1	$ 43,750.00
" 2	2,500.00
" 4	26,875.00
" 5	34,250.00
" 6	20,625.00
" 7	5,500.00
" 8	21,250.00
" 9	24,000.00
" 10	15,000.00
Total earthwork .	$243,750.00

BRIDGES AND AQUEDUCTS. The bridges or aqueducts are estimated at $41.00 per lineal meter, and the masonry piers at $8.00 per cubic meter.

Section 1.

The line will cross six small arroyos, requiring 350 lineal meters of flume in all and 1,000 cubic meters of masonry for piers, returning walls and junction bays.

350 lineal meters of flume at $41.00 . .	$14,350.00
1,000 cubic meters of masonry at $8.00 . .	8,000.00
Excavation	500.00
Total	$22,850.00

Section 3. Crossing of the Encinas and Oregano Arroyos.

1,000 lineal meters of flume	$41,000.00
6,000 cubic meters of masonry at $8.00 . .	48,000.00
(Piers 6. meters high)	
Excavation	5,000.00
Total	$94,000.00

Section 7. Crossing of the Arroyo Bigotes.

100 lineal meters flume at $41.00 . . . $4,100.00

250 cubic meters of masonry $2,000.00
(Piers 1.5 meters high)

Excavation . . . . . $ 500.00

Total $6,600.00

Section 8. Crossing the Arroyo Blanco.

This section is a 200-meter aqueduct. The average height of the piers will be 25 meters. The foundation is solid rock.

200 meters of aqueduct at $42.00 per meter . . . $ 8,200.00

1,300 cubic meters of masonry at $11.00 . $14,400.00

Excavation . . . . . $ 300.00

Total $22,900.00

Section 11. Flumes for crossing the Arroyo Navajas and branches.

The section of the flume will be reduced as a considerable quantity of water will be used for irrigating lands above.

100 meters of flume at $30.00 . . . . $3,000.00

250 meters of masonry at $8.00 . . . $2,000.00

Total $5,000.00

Collecting the items under the heading Cost of Bridges, we have a total cost as follows:

Section 1 . . . . . $ 22,850.00

" 3 . . . . . $ 94,000.00

" 7 . . . . . $ 6,000.00

" 8 . . . . . $ 22,900.00

" 11 . . . . . $ 5,000.00

Total for Bridges . . $151,350.00

DIVERSION DAMS AND INTAKES.

Rio San Diego Dam. The dam across this river will be of concrete 60 meters long, 1.5 meters in width at the top and 3 meters wide at base. It will be 1.5 meters high above the bed of the stream, and will extend 0.50 meter below into the solid rock foundation. The river in flood times brings down great quantities of logs and trees; and the dam therefore requires to be unusually strong to resist the battering effect of the drift.

400 cubic meters of concrete at $16.00 a meter	$ 6,400.00
200 cubic meters of masonry at intake, at $10.00	$ 2,000.00
300 cubic meters of rock excavation at $3.00	$ 900.00
Head gates and valve houses	$ 7,000.00
Diversion of water and coffer dams . . .	$ 3,000.00
Total	$19,300.00

Arroyo Tecolote Dam. This dam will be 30 meters long and one meter high with a foundation of solid rock. There being but little water in the river during the dry season the construction of the dam will present no difficulties.

140 cubic meters of concrete at $10.00	$1,600.00
40 cubic meters of side walls at $10.00	$ 400.00
Excavation	$ 200.00
Total	$2,200.00

Rio San Rodrigo Dam. A broken dam 200 meters long is contemplated here which will be inexpensive. Masonry walls at the intake and head gates to protect the canal against flood will be

necessary.

150 cubic metres of masonry at $10.00 . . .	$1,500.00
Head gates	$1,000.00
Excavation	$ 250.00
Drain dam	$ 300.00
Total	$3,050.00

Summarizing the above, the total cost of dams and intakes is $21,050.00

CLEARING.

From the San Diego river to the Tecolote Arroyos there are 14 kilometers less 3 kilometers of tunnel and crossing of Oregano Arroyo . . . . . 11 Kilometers

From the Diversion dam in the Tecolote Arroyo, kilometer 35, to the irrigable lands, kilometer 57.5 . . . . . 22.5 -do-

Total . . . . . 33.5 -do-

33.5 Kilometers of clearing at $100.00 . . $3,350.00

SUMMARY OF COST.

Uniting the above detailed items we have the total estimated cost of Line A from the San Diego river to the irrigable lands -- Kilometer 57, as follows:

Cost of Earth Work	$ 243,780.00
" " Bridges and Aqueducts	$ 151,350.00
" " Dams and Intakes	$ 21,050.00
" " Clearing	$ 3,350.00
Engineering and Superintendence at 10%	$ 41,953.00
T O T A L	$ 461,483.00

ESTIMATE OF COST OF LINE B.

EARTH WORK.

Section 1. From Intake to Kilometer 5.

This line is identical with that of Line A [illegible] as under:

25,000 cubic meters solid rock
at $1.25 . . . $31,250.00

25,000 cubic meters loose rock
at $0.50 . . . $12,500.00

Total $43,750.00

Section 2. Kilometer 5 to Kilometer 6.5.

This section is similar to that of Section 2 -- Line A and as under:

10,000 cubic meters of material at
25 cents per cubic meter . . . . .$ 2,500.00

Section 4. From Kilometer 7 to Kilometer 15.

This line will pass around the west and north side of the Palmero Hills where the country is very much broken by water courses coming down the hill side. There will be 15 crossings in this section requiring 1,000 lineal meters of bridging. At Liebre Pass the cut will be four meters, and I estimate the average cutting for the entire section to be 2.5 meters. The material is earth and loose rock, slope 1 to 1. Four kilometers of the line will require lining with cement and gravel to prevent filtration.

100,000 cubic meters of earth at
20 cents per meter $20,000.00

70,000 meters of loose rock at
50 cents per meter $35,000.00

4,000 lineal meters of lining
at $12.00 . . . . . .$48,000.00

Total $83,000.00

Section 5. Kilometer 15 to Kilometer 21.

The country is very smooth and regular and the material is earth.

60,000 meters of earth @ 20 cents $12,000.00

From this point to Diaz the lines are identical and the cost of the remaining sections are given under the heading of Line A.

SUMMARY OF COST OF EARTHWORK FOR LINE B.

Grouping the cost of the Sections already detailed under Line B and adding Sections 8, 9, and 10 of Line A we have the following total:

Section 1	$ 43,750.00
" 2	$ 2,500.00
" 3	$ 33,000.00
" 5	$ 12,000.00
" 8 of Line A	$ 21,250.00
" 9 -do-	$ 24,000.00
" 10 -do-	$ 15,000.00
Total . .	$201,500.00

BRIDGES AND AQUEDUCTS. The bridges or aqueducts are estimated at $41.00 per lineal meter, and the masonry piers at $7.00 per cubic meter.

Section 1. Identical With Line A.

The line will cross six small arroyos requiring 350 lineal meters of flume in all, and 1,000 cubic meters of masonry for piers, retaining walls and function bays.

350 lineal meters of flume at $41.00	$14,350.00
1,000 cubic meters of masonry at $7.00	$ 7,000.00
Excavation	$ 500.00
Total	$21,850.00

Section 7. Crossing of the Arroyo Seco.

This section is a flume 1,200 meters in length.

1,200 meters of flume at $41.00	$ 49,200.00
7,000 meters of masonry at $8.00 . . .	$ 56,000.00
Foundations	$ 6,000.00
Total	$111,200.00

Section 8.

1,000 linear meters of flume at $41.00 .	$41,000.00
6,300 cubic meters of masonry at $8.00 .	$50,400.00
Excavation	$ 2,600.00
Total	$94,000.00

Crossings of the Arroyon Piedras, Plomo, and Javejna are the same as described in sections 7, 8, and 11 of Line A.

SUMMARY OF COST OF BRIDGES.

Grouping the items under the heading of Bridges and Aqueducts, and including Sections 7, 8, and 11 of Line A we have the total cost as follows:

Section 1	$ 22,350.00
" 3	$111,200.00
" 4	$ 94,000.00
" 7 of Line A	$ 6,000.00
" 8 -do-	$ 22,900.00
" 11 -do-	$ 5,000.00
Total for bridges.	$262,550.00

DIVERSION DAMS AND INTAKES. The cost of dams and intakes in the San Diego River, Arroyo Tecolote, and San Rodrigo River will be the same as described under Line A, and is $ 21,050.00

CLEARING. From the intake in San Diego river to the Temecula Arroyo there are 21 kilometers less 1 kilometer -- the crossing of the Ora ano -- which are 20 kilometers. From the Temecula Diversion Dam in the Temecula Arroyo -- Kilometer 35 -- to the irrigable lands at Kilometer 57.5 there are 22.5 kilometers, making a total of 42.5 kilometers.

42.5 Kilometers at $100.00 . . . . $ 4,250.00

Uniting the whole of the items, we have the total cost of Line B from the San Diego River to the irrigable lands below Murrieta -- Kilometer 57.5.

Earth work	$ 201,500.00
Bridges and Aqueducts	$ 308,350.00
Dams and intakes	$ 21,050.00
Clearing	$ 4,250.00
Engineering and superintendence at 10 % . . .	$ 48,935.00
TOTAL COST OF LINE B .	$ 538,285.00

COMPARISON OF LINES A AND B .

QUANTITIES.	LINE A	LINE B
Total length of line	57.5 K.	64.5 K.
Total length of canal	36.5 K	43.5 K
Length of tunnel	2,000 M's	----
Length of bridging	1,750 M's	2,950 M
Total cubic meters masonry	10,355	17,490
Total meters lining	1,000	4,000

COST.	LINE A	LINE B
Earth Work	$243,780.00	$201,500.00
Bridges and Aqueducts	$151,350.00	$262,550.00
Dams and Intakes	$ 21,050.00	$ 21,050.00
Clearing	$ 3,350.00	$ 4,250.00
General Expenses (10%)	$ 41,253.00	$ 43,935.00
Total	$461,443.00	$538,285.00
Difference in favor of Line A.		$ 76,842.00

Line A was accordingly adopted although at first sight it might appear that a tunnel 2,000 meters long (which was afterwards extended to 2,200 meters) would prove an insurmountable obstacle to the project.

As a basis of this estimate trial lines were run from Tisbor to the intake, and from Kilometer 7 on Line A to the Tenolote Arroyo. Subsequently the original plan was changed because of the failure on the part of the promoters to agree among themselves regarding the relative value of the land to be irrigated as compared with that of the water with which it was to be irrigated, and from

lands were secured in the valleys of the Tecolote and Pigeon. These lands besides being inferior in quality are farther from the railway and consequently the cost of transportation of the products to the market is much increased.

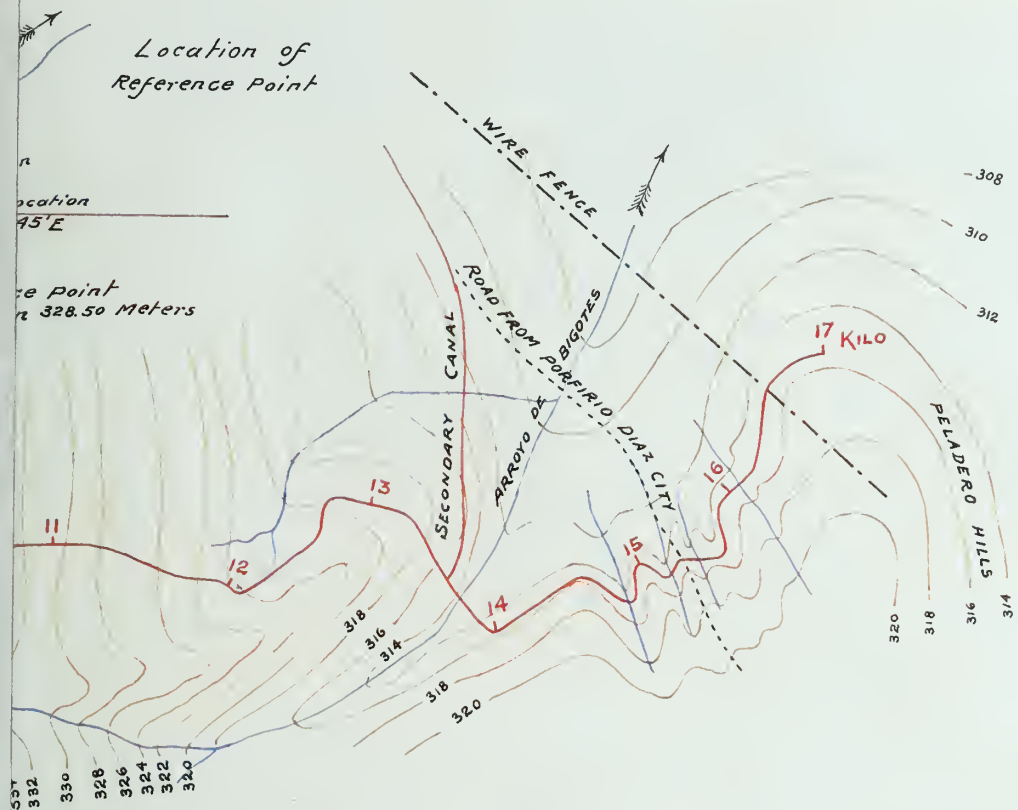
LOCATION.

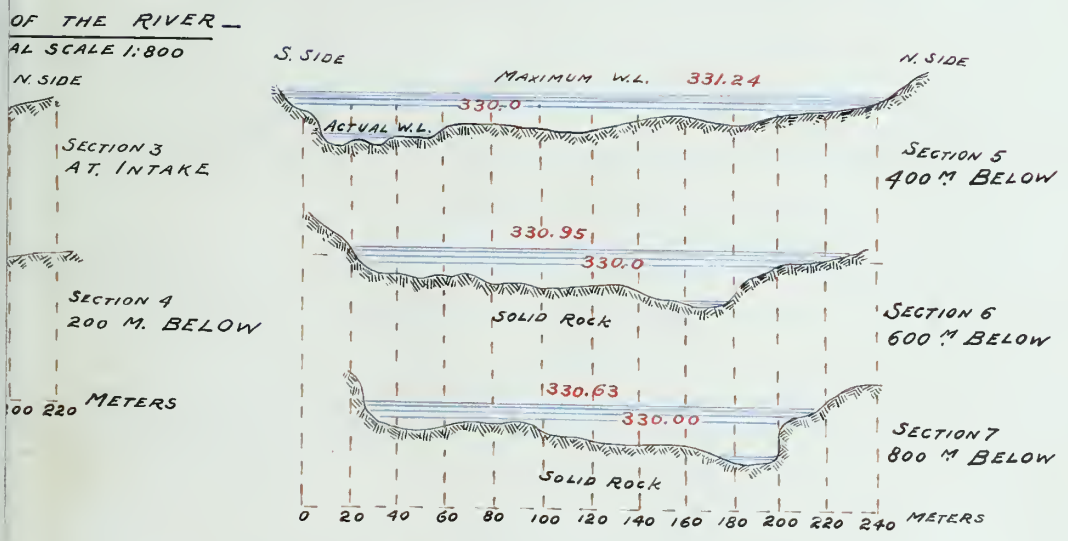
The main canal is 17 kilometers in length to the beginning of the main body of irrigable lands in the Soledad plain, and from thence forward the water is carried in secondary canals. Beginning at the intake in the San Diego river the line follows practically Line A. The elevation of the base of the canal was fixed at the bottom of the river which at that time carried one meter of water. This point is 725 meters above sea level. Wherever practicable the line was so located that the cutting on the lower side would at least equal the depth of water in the canal when receiving the full amount granted by the concession -- 6,000 liters per second. Where this could not be done without too great a cost or too distorted an alignment, earth banks or masonry walls were provided for the lower side. At every change of alignment curves were introduced, the minimum radius admitted being 50 meters.

The established grades were as follows:

From the intake to the Arroyo Encinas	0.40	meters per kilometer
Crossing the Encinas and Oregano Arroyos	2.00	" " "
From the Oregano to Kilometer 9	0.40	" " "
Through the tunnel and deep [illegible]	1.00	" " "

The shortest crossing of the Encinas and Oregano Arroyos was much above the shortest tunnel site; and as a consequence there


Location of
Reference Point
WIRE FENCE
ROAD FROM PORFIRIO DIAZ CITY
SECONDARY CANAL
ARROYO DE BIGOTES
17 KILO
PELADERO HILLS
11
12
13
14
15
16
308
310
312
314
316
318
320
322
324
326
328
330
332


OF THE RIVER
AL SCALE 1:800
N. SIDE
SECTION 3
AT. INTAKE
SECTION 4
200 M. BELOW
220 METERS
S. SIDE
N. SIDE
MAXIMUM W.L. 331.24
330.0
ACTUAL W.L.
SECTION 5
400 M BELOW
330.95
330.0
SOLID ROCK
SECTION 6
600 M BELOW
330.63
330.00
SECTION 7
800 M BELOW
SOLID ROCK
0 20 40 60 80 100 120 140 160 180 200 220 240 METERS

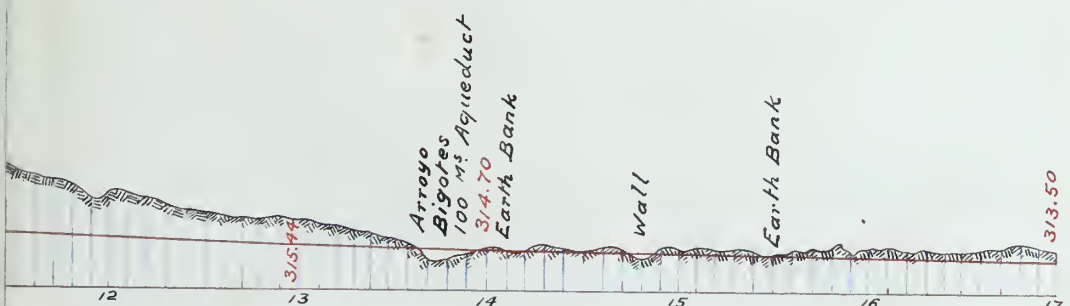

Arroyo Bigotes
100 Ms. Aqueduct
314.70
Earth Bank
Wall
Earth Bank
313.50
315.44
12
13
14
15
16
17
KILO

PLATE II.

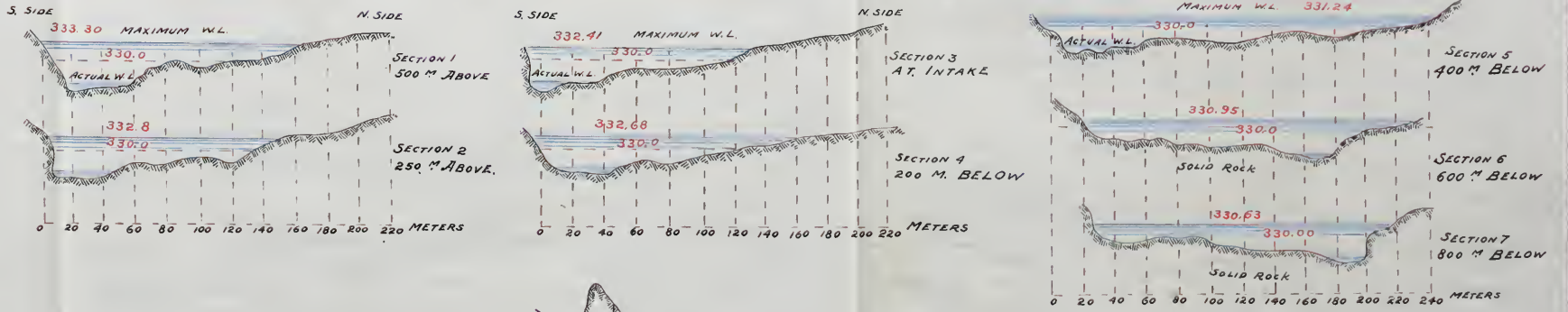
SAN DIEGO CANAL.

— LOCATION MAP AND PROFILE —

— SCALE 1: 40.000 —

— SECTIONS OF THE RIVER —

VERTICAL SCALE 1:800



— PROFILE —

{ HOR.: SCALE = 1:40,000
{ VERT: D° 1:1000

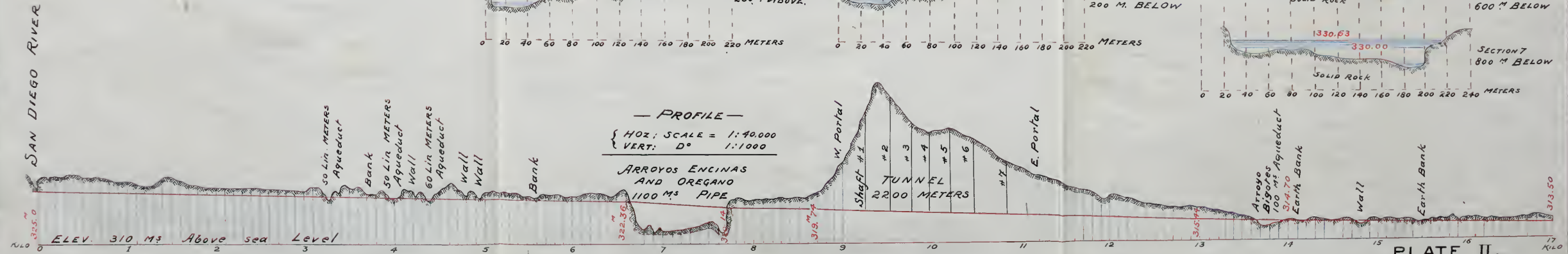


PLATE II.

was nearly a kilometer of extra development obtained between the Oregano and the tunnel. Passing the tunnel the location followed a small water course to reduce as much as possible the depth of excavation. At kilometer 13 + 600 meters a side dit or lateral the main canal to irrigate lands to the north of the Pirotes Arroyo. Passing the Pirotes the line twists around a wide hill, crossing a number of short water courses. No provision was made for the storm water of these streams, it was allowed to discharge into the canal. At kilometer 17, the main line is divided into two secondary canals. One follows the divide between the Tecolote and the Pirotes Arroyos; the other crosses the Tecolote to irrigate lands to the south.

PLATE II shows the alignment and profile of the location and cross sections of the river, also the location of the reference point, as provided by the Department.

Below the intake a masonry aqueduct -- or measuring weir -- was constructed, the height of the wall on the lower side being such that any excess water over the prescribed amount would flow into the river below. This weir is 30 meters in length. The depth of water in a normal section of the canal is the same as that in the measuring weir.

For the theoretical determination of the dimensions of the section of the measuring weir I have followed the method prescribed by the Department of Public Works.

Let Q = discharge per second = 6 cubic meters;

Y = depth of the water;

Y = [illegible] section of the aqueduct;

A = area of the section = X Y; - - - - - - - - - - - - - - (1)

(the walls being perpendicular)

P = wet perimeter = 2 X + Y; - - - - - - - - - - - - (2)

R = hydraulic radius = $\frac{X\ Y}{2\ X + Y} = \frac{A}{P}$; - - - - (3)

I = inclination of canal = 0.0004;

V = velocity in meters per second = $C\sqrt{R\ I}$;

C = constant, which according to Kutter for metric measure is

$$\frac{23 + \frac{0.00155}{I} + \frac{1}{n}}{1 + (23 + \frac{0.00155}{I})\frac{n}{\sqrt{R}}};$$

n = coefficient of friction, which for a plastered cement surface is assumed to be 0.011.

If there is no definite reason for fixing beforehand the values of X or Y, they may be proportioned so as to give a maximum flow for a given area, or what is the same thing, that

$P = \frac{A}{R}$ be a minimum quantity.

We have, combining formulas 1, 2, 3.

$$P = \frac{A\ Y}{2\ A + Y^2}$$

For a minimum value of Y, $\frac{d\ P}{d\ Y} = 0$; or

$$\frac{2\ A^2 + A\ Y^2 - 2\ A\ Y^2}{(2\ A + Y^2)^2} = 0;\ \text{hence}\ 2\ A = Y^2 = 2\ X\ Y,$$

or $Y = 2\ X$.

That is, for a maximum flow through a given rectangular area the depth is one half the width.

By making X = 1/2 Y, we have:

$$A = \frac{Y^2}{2};$$

$$P = 2\ Y;$$

$$R = 1/4\ Y;$$

$$C = \frac{117.784\sqrt{R}}{\sqrt{R} + 0.2956}$$

$$V = \frac{0.58892\ Y}{0.5\sqrt{Y} + 0.2956},$$

Q = discharge in cubic meters per second

$$= A\ V = Q = \frac{0.29446\ Y^3}{0.5\sqrt{Y} + 0.2956}$$

whence

$$Y^3 - 10.138\sqrt{Y} = 6.023.$$

Solving this we have:

Y = 2.8535;

X = 1/2 Y = 1.42675;

A = 4.0714;

V = 1.474 and

Q = 6.

For the solution of the above equation, the same method was pursued as indicated in the more complex case of the determination of the width of the base of the canal as shown hereafter.

The value then of X, or depth of water in the measuring weir when running full, is 1.4267 meters, which is also the depth of the water in the canal when there is a flow of 6 cubic meters per second.

For the determination of Y -- the width of the canal -- we have:

X = 1.4267

S = the angle that side slopes make with the horizontal

= 45°;

N = coefficient of friction = 0.025, which for canals in earth and loose rock is probably as near the truth as

n = 0.011 for the cement plaster;

A = area = $XY + X^2$ = 1.4267 Y + 2.0365 - - - - - (4)

$$P = Y + \frac{2Y}{\sin^2 a} = Y + 4.23532; \quad - - - - - - - - (5)$$

$$R = \frac{A}{P}; \quad - - - - - - - - - - - - - - - (6)$$

I = inclination of the canal = 0.0004,

$$C = \frac{60.275\sqrt{R}}{\sqrt{R} + 0.6719}; \quad - - - - - - - - - - - (7)$$

$$V = C\sqrt{RI} = \frac{1.2375\sqrt{R}}{\sqrt{R} + 0.6719}; \quad - - - - - - - - - (8)$$

$$Q = a \cdot V = \frac{1.2375\, A\sqrt{R}}{\sqrt{R} + 0.6719} \quad - - - - - - - - - - (9)$$

Substituting for Q its value as given :

$$Q\sqrt{\frac{A}{P}} = \frac{1.2375\, A^2}{P} = 4.0314, \text{ or } - - - - - - (10)$$

$$36 A P = 1.7889 A^4 - 10.784 A^2 P + 10.2521 P^2 - - - (11)$$

From formulæ (4) and (5) we have:

$$P = 0.10092 A + 2.6086 - - - - - - - - - - - - (12)$$

Substituting this in (11)

$$A - 4.2253 A^3 - 25.367 A^2 - 10.329? A + 62.48 = 0. \quad (13)$$

For the solution of this equation to a close degree of approximation I have proceeded as follows:

By the use of prepared tables found in engineers' hand books, for the value of C under varying conditions it is seen that Y = 4 is not far from the truth. Substituting this in equation (4) we have for an approximate value, A = 7.73 = A_1. Let (dA_1) be the increment to be added to the trial value, A_1 to produce A, that is, $A_1 + d A_1 = A$. Substituting this in (13), using first powers of $d A_1$ only we have:

$$A_1^4 + 4 A_1^3 d A_1 - 4.2253 A_1^3 - 12.6759 A_1^2 d A_1 - 85.367 A_1^2$$
$$- 50.734 A_1 d A_1 - 10.329? d A_1 - 10.329? A_1 + 62.48 = 0 \quad (14)$$

By giving to A_1 its value 7.73 in equation (14) we have :

$778.672 d A_1 = -15.958$ d $A_1 = -0.0235$ and $A = A_1 - 0.0235 =$ 7.7065.

SAN DIEGO CANAL.

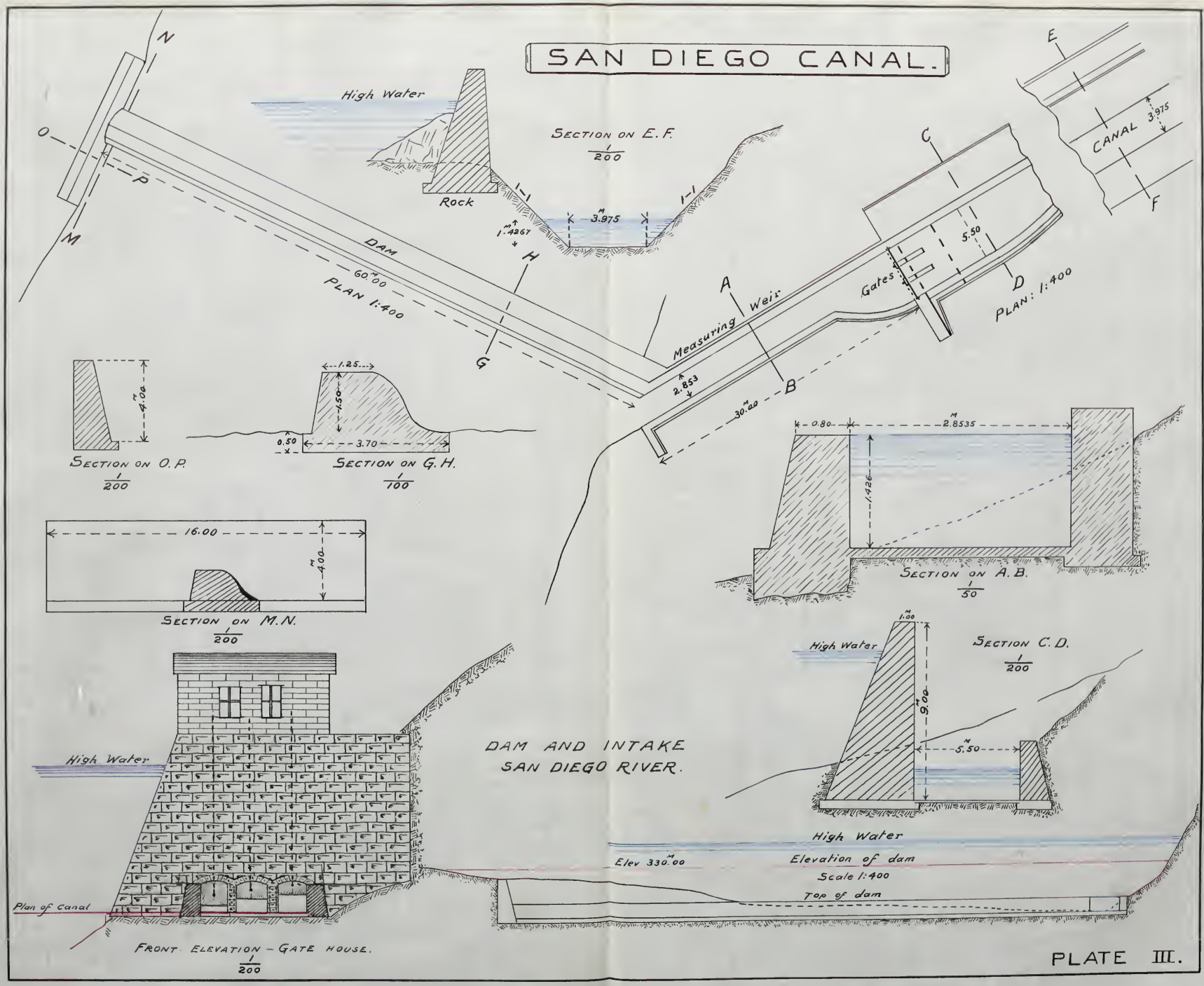


PLATE III.

Then from equation (4) we have :

$V = 3.075$ meters, the velocity at the canal.

Should the value of V thus obtained be not sufficiently close, it may be used a second assigned value of A_1, and if this new value the solution of equation (14) will usually give to a value to the desired degree of approximation.

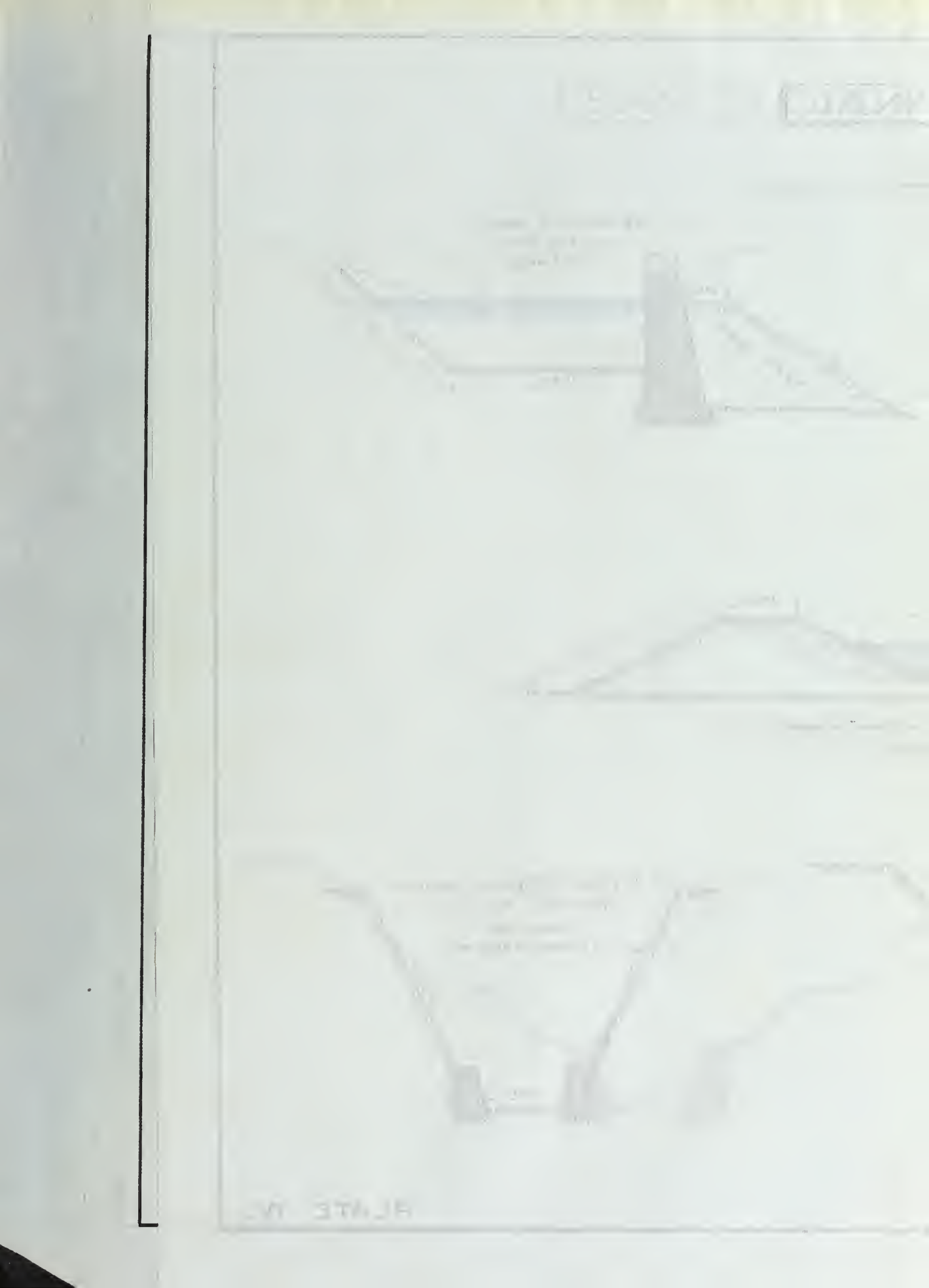
The above may seem an unnecessary refinement, but it is demanded by the Department.

CONSTRUCTION.

EARTH AND EARTH WORK. The dotted area will divert from the river across the intaking weir 30 meters in length. The curtain falls over the lower side of the river. The construction of the weir is rubble laid in cement, the sides and bottom being plastered with cement and so on. PLATE III shows the details of the end headworks.

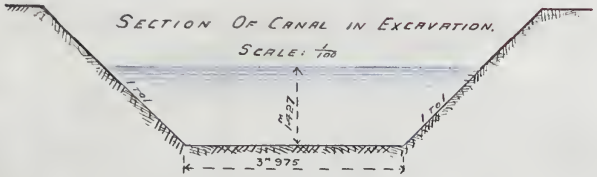
Passing the intaking weir the water enters the canal proper by three openings, each 1.50 meters wide, and provided with gates which may be closed in flood time. Below the head gates a masonry wall continues to higher ground to prevent flood water from entering the canal. Below the head gates the canal alone no item of particular interest, except at places where the cutting on the lower side was not sufficient, where earth embankments -- or masonry walls were provided. These are noted on the profile. Sections of the canal are shown on PLATE IV.

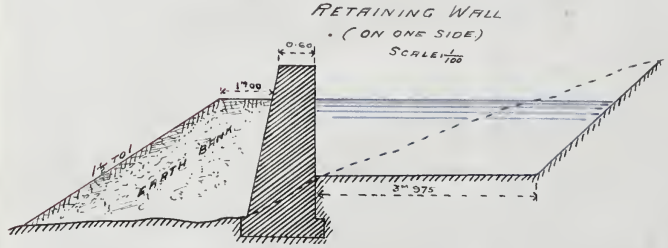
BRIDGES AND AQUEDUCTS. The aqueducts are of flumed pine. The coefficient of friction "c" is considered the same as that of

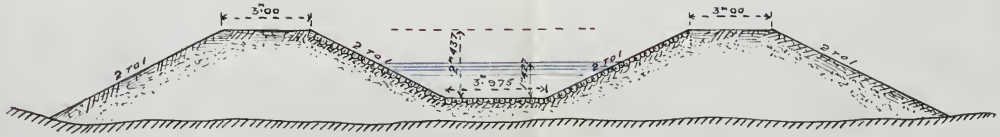


SAN DIEGO CANAL

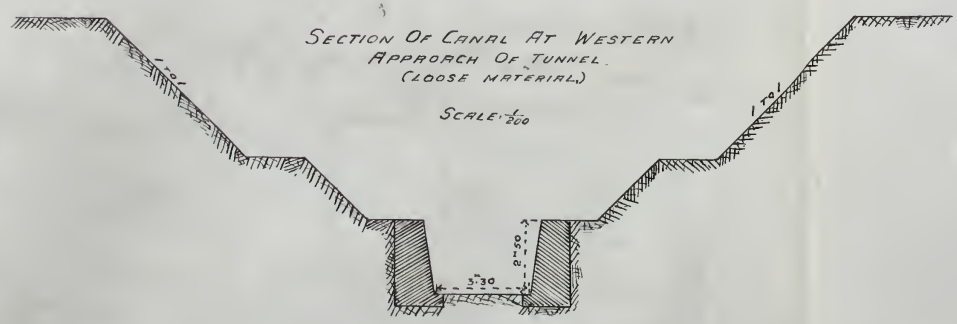
—THE CANAL.—







SECTION OF CANAL IN EMBANKMENT.
SCALE: 1/200



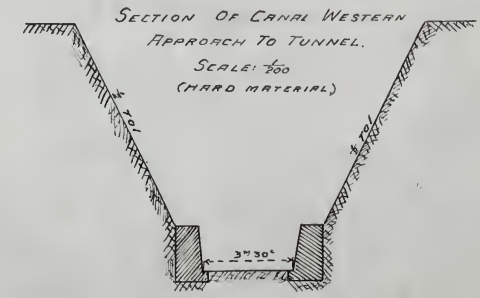


PLATE IV.

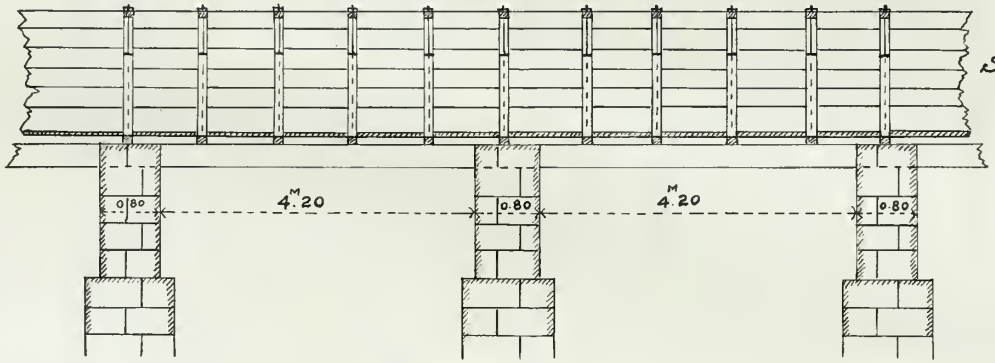
cement plaster. The wetted perimeter of the measuring weir, viz.: width 2.257 meters, and depth 1.487 meters. On account of the commercial size of the lumber the dimensions were changed to a width of 6' 6", and depth 5' 0". The ends of the aqueduct were joined to the earth by [illegible] of masonry. The planks that formed the aqueduct were joined together at the ends and also by plowing grooves into the planks, into which were inserted splines and covered with hot asphalt. Details of flume, bridge and junction will be shown on Plate V.

STEEL PIPE. The Arroyo Encino and Orgeno Cañon generally a small flow, but during the rainy seasons the stream become very much increased in volume. The bottom is of gravel permeated with water, and foundations sufficiently solid to support the piers for an aqueduct would be difficult to obtain. For this reason it was decided to build a steel pipe of the diameter required to convey the needed amount of water, and bury it at a sufficient depth below the bed of the stream to insure its safety against floods. The pipe was manufactured in New York and brought to the site in sheets punched for double rows of rivets 1/2 inch in diameter and 3 inches between centers. Each section consisted of two sheets. The sheets were each 6 feet in length. The steel was 1/2 inch in thickness in that part of the line where the depth below the hydraulic grade line was 20 feet or more, and 3/8 inch in diameter in the more shallow places. The pipe was assembled on the ground in sections, lowered into the trench 12 feet deep by a derrick, and riveted to the preceding section. Before lowering into the trench the pipe was [illegible] coated inside and out with asphalt.

BRIDGES AND AQUEDUCTS

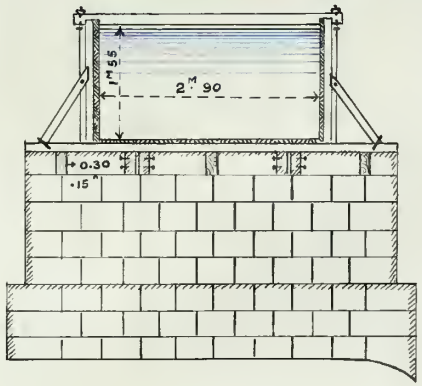
SAN DIEGO CANAL.

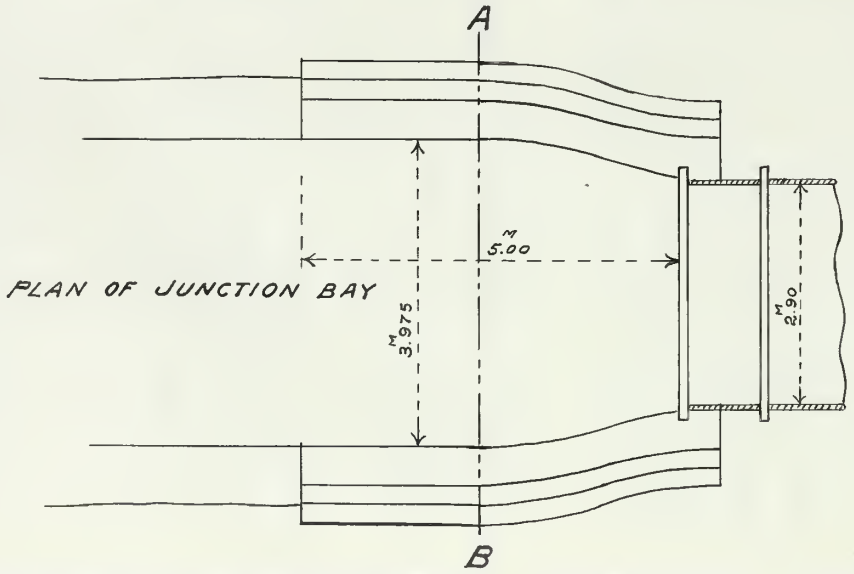
ELEVATION



SCALE: 1/100

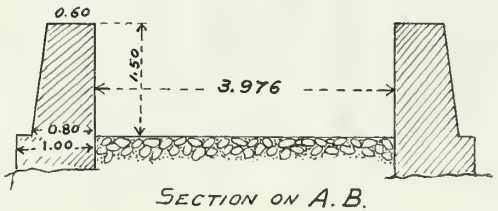
SECTION





PLAN OF JUNCTION BAY

METHOD OF JOINING TIMBERS.



SECTION ON A.B.

PLATE V.

Work was proceeded at both ends of the line, and when the point of junction was reached, the remaining section was fitted properly and the riveting was partially done. During the night the temperature fell below freezing point and the next morning it was found that the rivets at the final section -- one of which about one fourth of the total number had been driven -- had failed by shearing, and the two ends of the pipe were about 2 inches apart. By noon -- in the warm sunlight -- the two ends were brought into place, a collar was made and thoroughly riveted, and the entire trench was completely filled with earth and gravel. From that time no difficulty was ever experienced and the pipe (being below the surface of the ground and always full of water) remains practically at constant temperature.

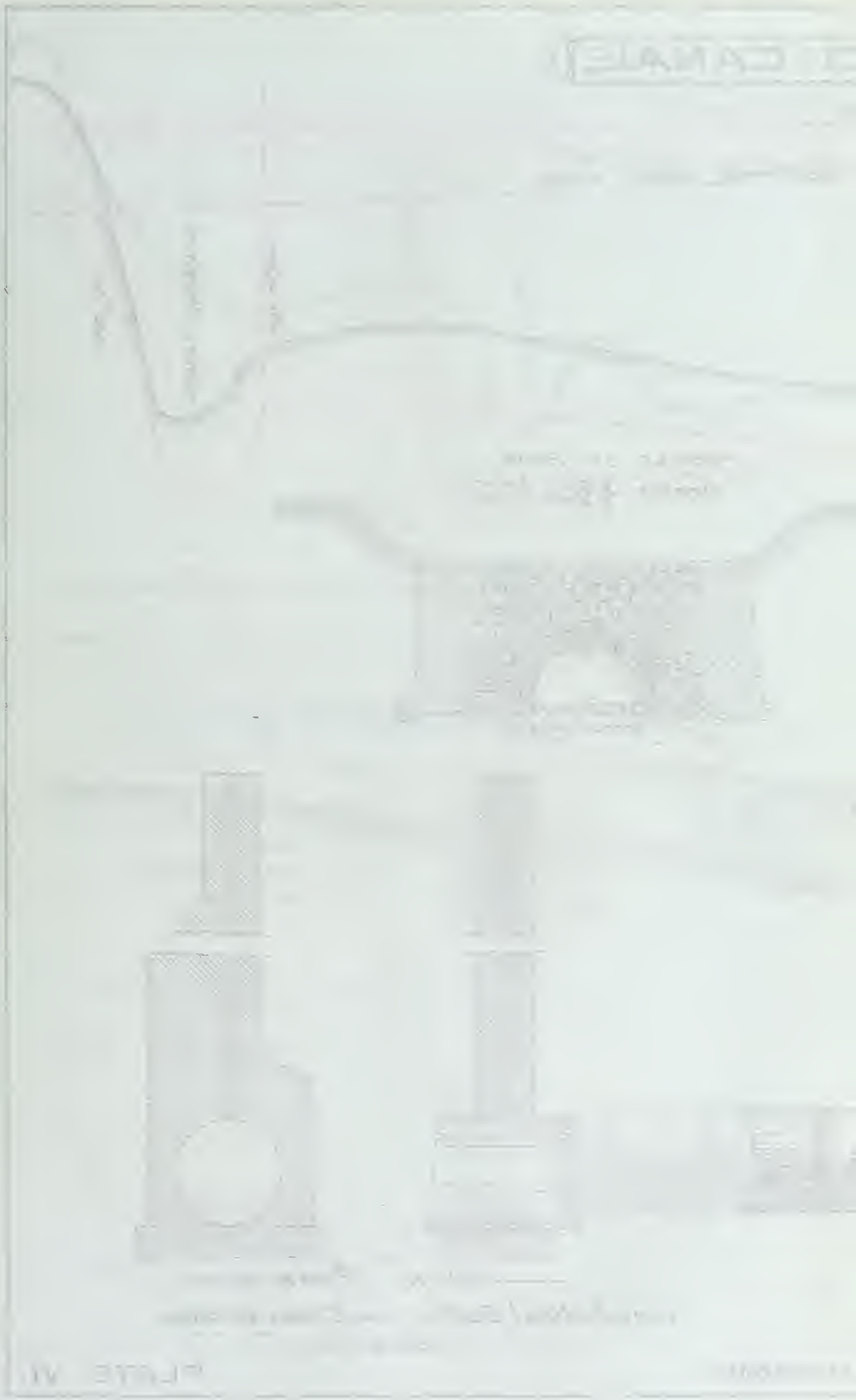
The air valves are established at high points in the line connected to a pipe just extending above the hydraulic grade. These pipes were protected against flood by many pillars. Judging from the whistling of escaping air from the pipes the air valves seem to be quite necessary to prevent reduction in the effective section.

Connection between the pipe and the conical gate effected by flanged ends provided with iron gratings to prevent foreign matter from entering. Details of the pipe are shown on PLATE VI.

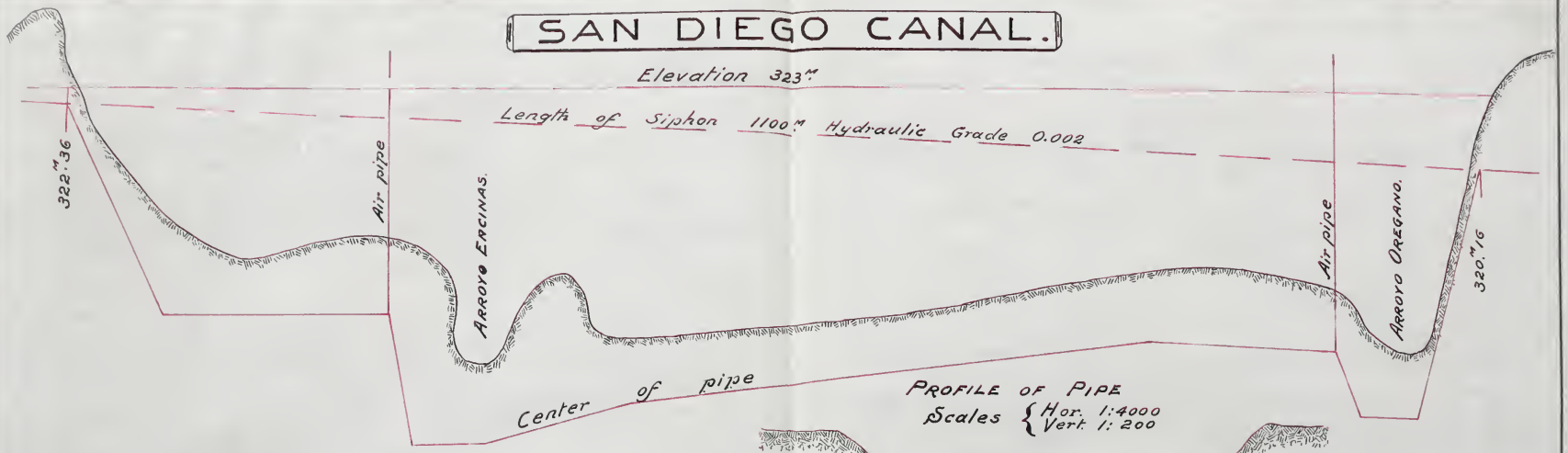
The pipe -- or inverted syphon -- leaving where its bottom is the difference of elevation between the two ends being 2.20 meters. For the exact determination of the radius we have the following formulae:

r = radius of the pipe;

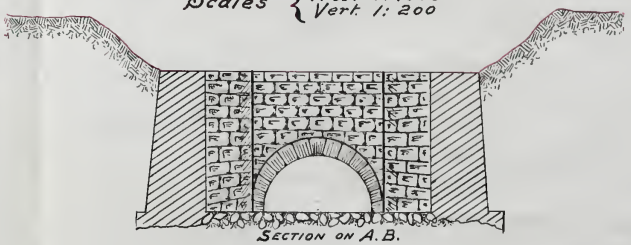
π = 3.1416;



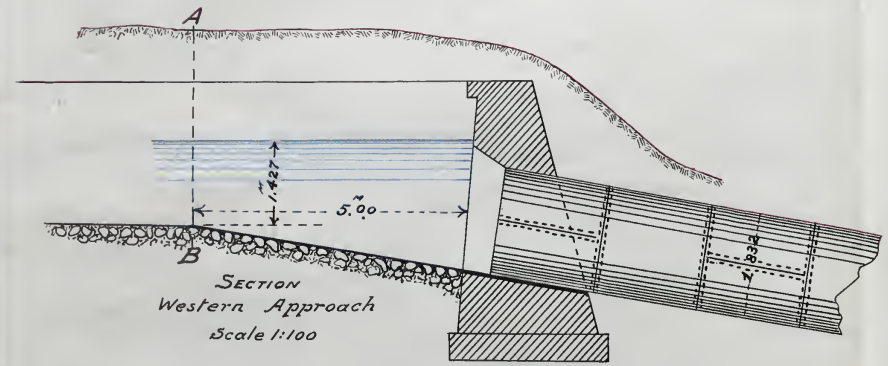
SAN DIEGO CANAL.



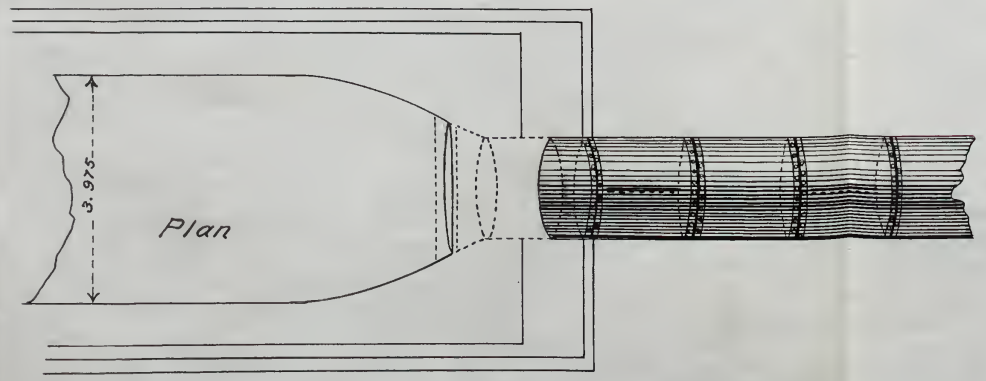
PROFILE OF PIPE
Scales { Hor. 1:4000
Vert 1: 200

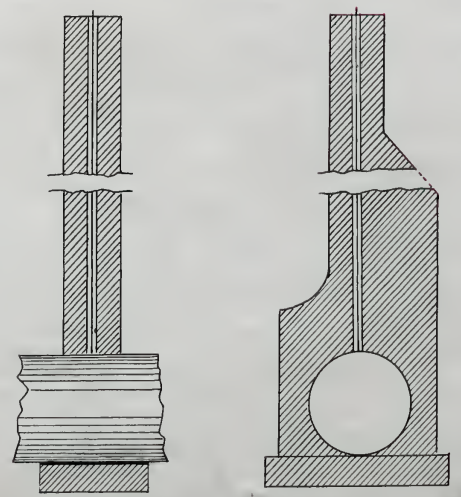


SECTION ON A.B.



SECTION
Western Approach
Scale 1:100





AIR PIPE.
Longitudinal Section — Cross Section.
Scale 1:100

INVERTED SIPHON.

PLATE VI.

C = coefficient = $\frac{1}{n}R^{1/6}$,

S = slope = 0.002,

V = velocity = $C\sqrt{RI} = 0.031\frac{1}{n}\sqrt{x}$,

Q = discharge in cubic meters per second = $a = 1.0)(C) \cdot x^{\frac{5}{2}}$

From Kutter's formula, making n = 0.010 we have :

$$\frac{10/.1\sqrt{x}}{\sqrt{x} + 0.0023} ;$$

$$Q = a = \frac{10.1\sqrt{x}\ x^3}{\sqrt{x} + 0.0023} .$$

From this $x^3 - 0.3043\sqrt{x} = 0.0011$.

Hence, x = 0.720 meter.

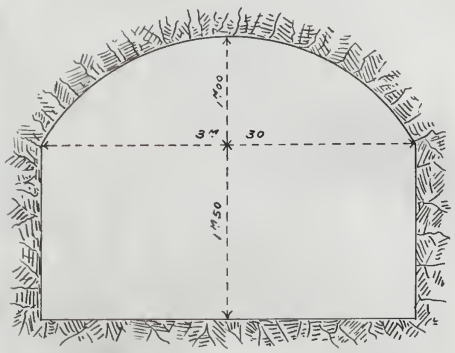
TUNNEL. The grade through the tunnel is one meter per kilometer. The vertical scale in the drawing, Plate 30, is one inch = 1.50 meters. When the tunnel is running full, the water is supposed to reach the spring line only. The width of the tunnel -- calculated by the formulae previously given using for "R" a value of 0.020 -- was fixed at 3.30 meters to be a trifle more than two decimeters. The section of the tunnel is in the form of an arch with a rise of 1 meter.

Owing to the serious hazard, placed by irregular deposits, that would arise from any advance to facilitate the work, the temporary relief by means of the shaft at Km. 4 was not built. The greatest distance between shafts is 700 meters. The length of the line at the bottom of the shaft was the projection of the line and 1.5 meters. Since 700 meters in length, prolonged from such a base would be error of 5 millimeters at the point of intersection. The alignment was carried down the shaft by means of optical square and, checked by a transit at right angles. The object of the transit was partly to ... and partly to ... tunnel, a matter of small, and to adjustment.

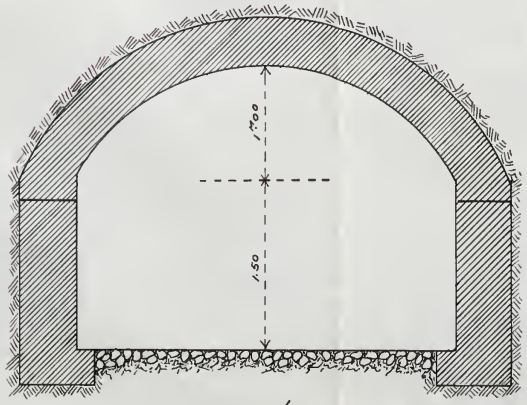
SAN DIEGO CANAL.

— THE TUNNEL. —

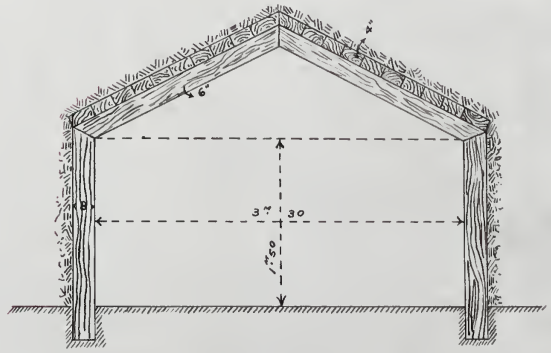
SECTION IN SOLID ROCK.



SECTION LINED WITH MASONRY

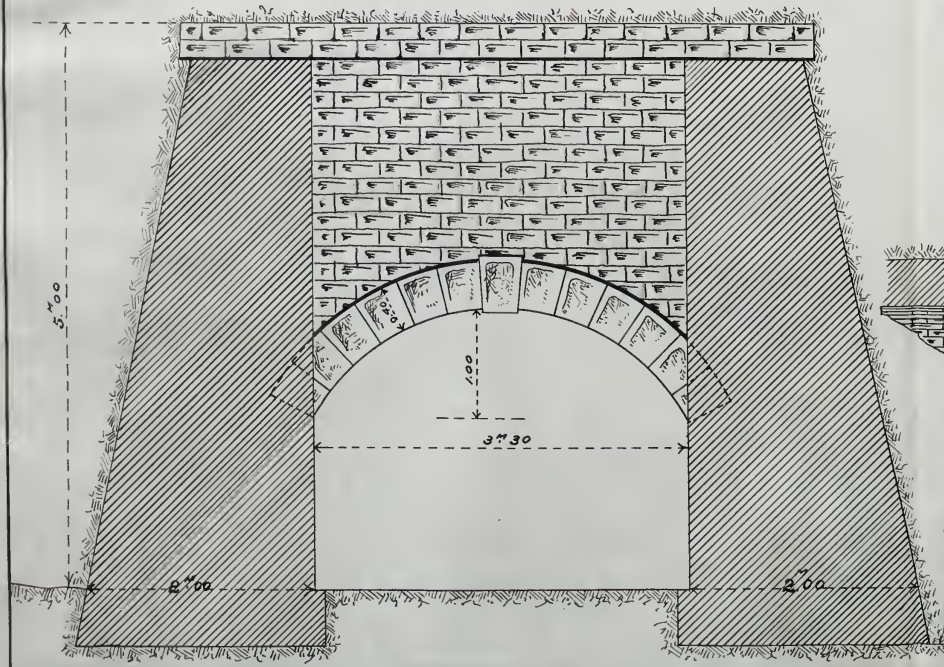


SECTION LINED WITH TIMBER.



SCALE: $\frac{1}{50}$

WESTERN PORTAL AND SIDE WALLS.



LONGITUDINAL SECTION OF WESTERN PORTAL.

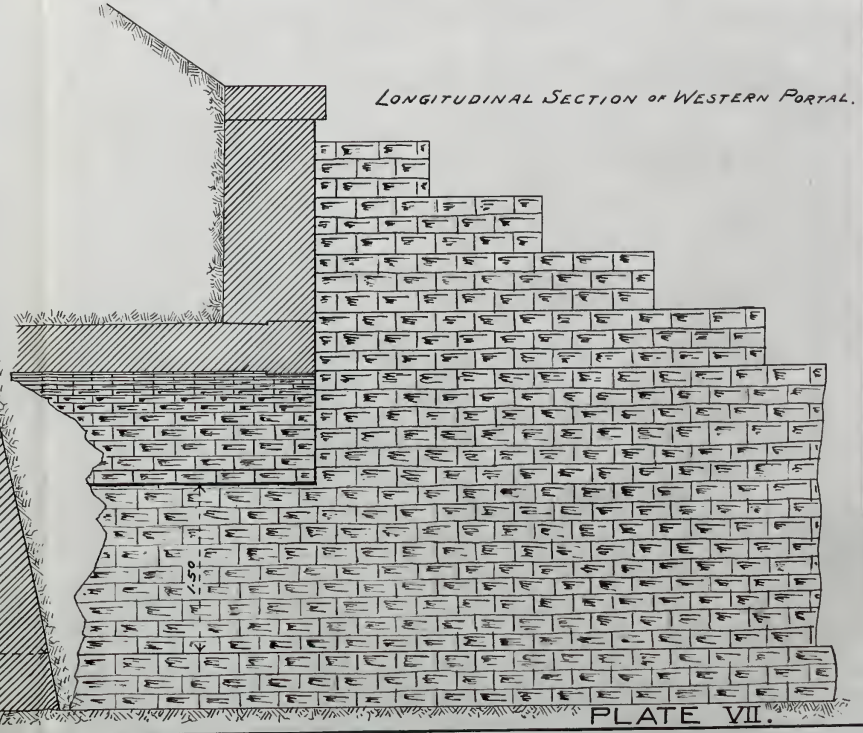


PLATE VII.

The instrument was placed in line on the surface, over the shaft, and adjusted till the cross hairs followed the plumb-line hung to the bottom, the two blankets and vessel were removed to the point fixed. Whether possible the illumination was done by reflecting sunlight down the shaft by the aid of mirrors.

Sufficient ventilation for the workmen was furnished by a blower or fan worked by a boy. Fresh air was forced through the shaft by a derrick, with block and tackle moved by a whim. At the eastern end the material was raised; the tunnel had to be lined for a distance of 50 or 60 feet with masonry. Elsewhere timber sets were fixed vertically, the sides of two tunnel being connected to receive the posts.

At the beginning it was attempted to use hand power drills, the drill being thrown forward by a powerful spring; but owing to the difficulty and time lost in replacing drills after a blast, two were abandoned and the work was finished with hammer and steel.

A section of the tunnel as period during masonry work is shown on PLATE VII.

OTHER PARTS OF THE WORK.

The [illegible] of 17 kilometres [illegible], from the fall [illegible] to the point where the irrigation of the [illegible] and the main canal becomes navigable. According to the specification granted by the Peruvian Government, all material was admitted free of duties. The whole of the work was [illegible] Two prizes varied not only with the classification of material, but also with the depth of excavation. Common earth could not be classified, because of the deficient proportion of earth, loose rock, and solid rock.

CANAL WORK. Under this head is included all excavation and all construction, except for the foundations of the dam and locks for the tunnel. The amount of lining, as will be noticed below the original estimate and many embankments were riprapped -- and retaining walls were substituted. The water from small water courses was allowed to enter the canal.

EXCAVATION (Classified)

Earth : 27,200 meters at 16 cents	$ 4,352.00
Gravel : 15,250 meters at 30 cents	$ 4,575.00
Broken: 51,320 meters at 50 cents	$ 25,663.00
Loose rock : 4,500 at 65 cents	$ 2,925.00
Solid rock : 41,340 meters at $1.25 . . .	$ 51,675.00

EXCAVATION (Unclassified)

Kilometer 9*: 11,365 meters at 90 cents . .	$ 10,228.50
Kilometer 10*: 12,729 meters at $1.03 . .	$ 13,110.87
Kilometer 12*: 7,167 meters at $1.80 . . .	$ 12,900.60

EMBANKMENT.

Loose rock : 5670 cubic meters at 40 cents .	$ 2,268.00
Earth : 21,473 cubic meters at 16 cents . .	$ 3,435.68
Riprap . 482 cubic meters at $2.00 . . .	$ 964.00

EXTRA WORK.

Removing slides and repairing effects of freshet.	$ 3,210.20
TOTAL COST OF CANAL WORK . .	$142,753.23

* The prices paid for the unclassified excavation on Kilometers 9 and 12 was fixed according to the dept. of the excavation.

TUNNEL.

598 lineal [illegible] at $33.00	$ 20,448.00
1504 lineal meters at $45.00	$ 67,680.00
170 metres of shaft work at $28.50. .	$ 4,845.00
1125 cubic metres of masonry at $7.00 .	$ 7,875.00
Extra work putting in timber across the excavation for lining. . . .	$ 1,000.00
TOTAL	$107,494.00

WARPING AND RETAINING WALLS. The lining was very much reduced below the original estimate. In many places where flume was placed upon rock filled bank, it was decided both to line and pier masonry. There was constructed 200 lineal metres of wooden trestle, built entirely of pine.

MATERIAL.

60,000 feet rough pine at $50.00 per 1,000 feet	$ 3,000.00
40,000 feet dressed pine at $62.00 per 1,000 feet	$ 2,480.00
2,500 kilos of iron at 30 cents	$ 750.00
4 barrels of asphalt	$ 100.00
Freight from Pisa to site	$ 1,400.00

LABOR.

100,000 D. M. timber at $12.00 per M. . .	$ 1,272.00
740 cubic metres of masonry at $7.00 . .	$ 5,180.00
TOTAL DOCK TRESTLING AND MASONRY . . .	$14,482.00

PIPE UNDER THE TUNNEL AND OVERHEAD TROUGH. The length of pipe was 1,100 metres; the inside diameter 1,32 metres. The total weight was 650,708 kilogrammes, or 1,436,200 lbs. The cost of the pipe in New York City was 1 cent gold per pound, or $

Venezuelan currency.

1,450,000 kg. of steel pipe at 2 cents . . .	$ 29,224.00
Freight to Pire	$ 3,675.00
Freight to camp	$ 4,200.00
Cement	$ 8,500.00
60 cubic meters of masonry at $7.00	$ 350.00
Accessories of general expenses	$ 1,500.00
TOTAL COST OF PIPE	$ 53,349.00

DAM AND INTAKE. A temporary dam of earth was first built around the head of the intake, the canal was then excavated; and then the spillway, or overflow weir, and other masonry above the head gates built. The wood gates were then placed in position, and the water from the river diverted to the canal and allowed to return to the river below the dam. Temporary dams of earth were built above and below the site of the permanent work, and the construction then carried on. After the dam was completed, gates were closed and the walls below the head gates were built. The crest of the dam is at the elevation of the overflow weir -- approximately 1.50 meters above the bed of the stream. The dam is built of cement concrete.

The contract was given at a lump sum -- approximately divided as below:

Temporary dams	$ 1,200.00
Excavation	$ 500.00
Dam 315 cubic meters	$ 5,330.00
Other masonry about head works, approximately 1,000 cubic meters at $3.50	$ 3,500.00
Head gates placed	$ 2,[illegible].00

[illegible] . . . . . $ 300.00

Total cost of the [illegible] $16,055.00

CLEARING. The clearing for the right of way for the canal - 4 meters in width - was contracted at $75.00 per kilometre throughout the entire line; and hence the cost of clearing 17 kilometers at $75.00 was $1,275.00

ENGINEERING STAFF. The work was in progress 25 months, and the staff consisted of :

One consulting engineer (per month) . . .	$ 750.00
One construction engineer (per month) . .	$ 200.00
One assistant	$ 100.00
Labor roll — 5 men @ $1.00 per day . .	$ 150.00
Camp expenses	$ 300.00
Total per month	$ 1,130.00
TOTAL 25 MONTHS	$28,250.00

The above is a full estimate of the monthly cost per month of the engineering staff during location and construction.

SUMMARY OF ACTUAL COSTS.

Excavation of canal	$102,739.23
Tunnel	$104,[illegible]
Aqueducts and retaining walls	$ 14,[illegible]
Pipe under Kananaskis and Oregano Arroyos .	$ 53,340.00
Dam and head works	$ 16,[illegible]
Bridges	$ 1,[illegible]
Engineering	$ 28,[illegible]
General expenses (estimated)	$ 13,000.00
TOTAL COST	$[illegible]

COMPARISON BETWEEN THE ORIGINAL ESTIMATE AND THE FINAL COST.

The original estimate included the cost of Line A from the San Diego River to the Tecolote Arroyo, practically covering 17 kilometers of location. This is covered by sections 1 to 7 inclusive of the preliminary estimate.

ITEMS.	Cost from San Diego River to Tecolote Arroyo.	
	Actual Cost of Work	Original Estimate (Sections 1-7 inclusive) of Line A
Earth work, excavation and embankment	$142,739.23	$ 99,250.00
Tunnel	107,494.00	84,280.00
Aqueducts and retaining walls	14,482.00	29,450.00
Pipe under arroyos	53,349.00	94,000.00
Dam and headwork	10,655.00	17,300.00
Clearing	1,275.00	1,100.00 *
Engineering and general expenses	38,250.00	32,730.00
Total	$376,244.23	$345,710.00

The increased length of the location over the preconnaissance for Line A in the Tecolote Arroyo (3 kilometers) is caused in part by the Filmore Street development required between the eastern terminus of the syphon and the Century apartments, and in part by the fact that the original location began at a point below the point where Line A now crosses the Tecolote Arroyo.

* Based upon 11 kilometers of possible clearing, at $100.00 per kilometer.

It will be noted that the cost of the tunnel is much increased over the original estimate, due partly to the elimination of a number of wooden crossbeams -- temporary in nature -- and the subsequent construction of more permanent and satisfactory ones.

The tunnel and approaches were let at too low a price to an irresponsible party who left the work after the completion of about one third of his contract. This necessitated a re-letting of the remaining portions of the work at an increased price and to more nearly account for the increased cost of the canal and tunnel over the preliminary estimate.

The cost of the inverted syphon under the barrage was unnormally low, because the rise for material were let immediately after the Spanish war and the United States Government had on hand for sale a large supply of light arms [illegible] at a very low price.

I think in general it may be said that the most important work in an enterprise of this kind is the labor of the reconnoitering engineer, and however much his estimate may be backed by judgment and previous experience, there always enter elements unforseen.

DESCRIPTION OF THE LANDS TO BE IRRIGATED. There is a small tract of 450 acres lying in the bend between the Del Rio and the Grande Arroyo. These lands were put into cultivation before the crossing of the Guerrero and the canal was completed. They are the most fertile lands of the project. The [illegible] of the irrigable lands lie on both sides of the Piedras and Tecolote arroyos, also the Grande Arroyo. There are about 8,000 hectares of good tillable land in this tract, and a large area of [illegible] land that may be irrigated but is not cultivated when the water is sufficient. The general ground level is about 900

meters, and the latitude 29° N. Near the water courses the soil is a rich alluvial deposit of about 1.5 meters in depth. On the higher lands away from the Arroyos the soil is thinner, about 60 centimeters in depth.

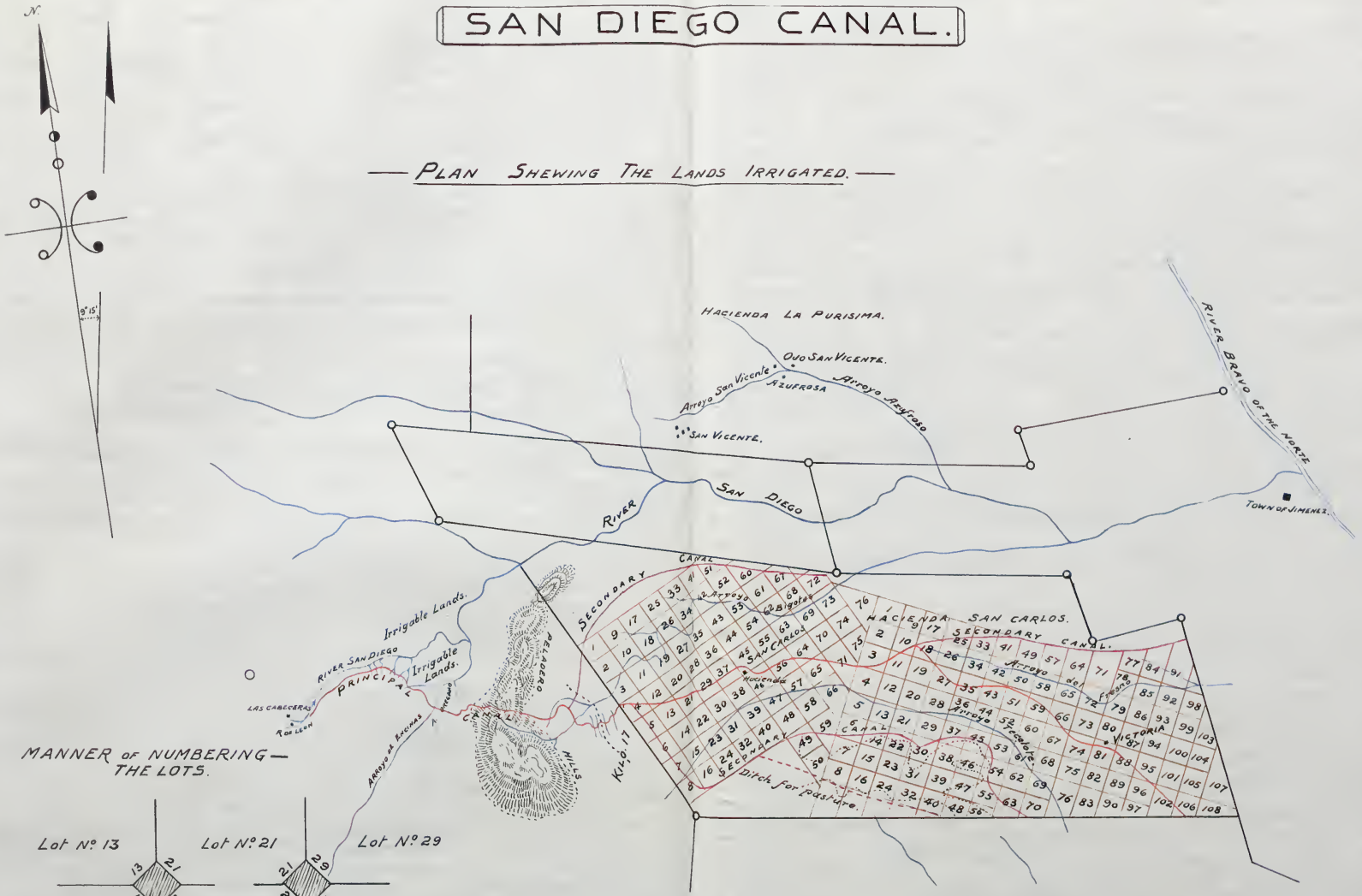
To facilitate the operations of the estate the lands were divided into sections of one square kilometer each. Stones were planted at the corners, and the four sides of each were cut numbers corresponding to the numbers of the adjacent lot. Descriptions of the lots were placed on file in the general office showing the extent of tillable land and other items of interest.

The inclination of the surface of the ground from the higher lands toward the water courses is somewhat steep for successful irrigation, being two or three meters per kilometer.

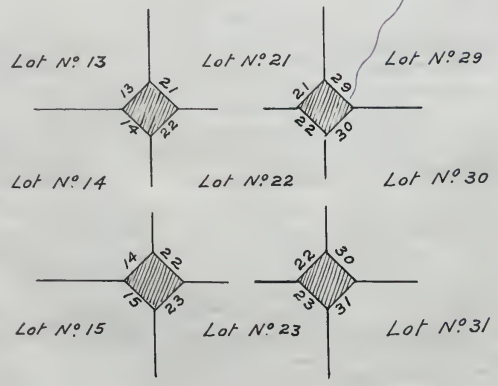
The nearest railway station to which the products of the property must be hauled is Ciudad Porfirio Diaz, 60 kilometers to the south of the central part of the estate. When this enterprise was begun there were no improvements upon the property nor people living thereon. The villages of Las Vacas, Jimenez and Moral lie within a radius of 25 kilometers of the main property, and contain approximately 6,000 inhabitants; but these people are more accustomed to riding horse-back than to guiding a plough, consequently all labor had to be brought from the interior of the Republic at great expense. Buildings of all kinds had to be erected, wide ditches dug, and the land cleared and opened for cultivation. The cost of all this, together with the price paid for the land brought the capital investment -- including the cost of the canal -- to a little more than one million dollars before the main body of the property was brought under cultivation.

SAN DIEGO CANAL.

— PLAN SHEWING THE LANDS IRRIGATED. —



MANNER of NUMBERING — THE LOTS.



— SCALE = 1: 200,000 —

PLATE VIII.

crops raised. Cotton did well for a few years, producing 400 kilogrammes of fibre per hectare (about 350 pounds per acre), but its cultivation has been practically suspended of late owing to the damage caused by the boll worm. Sugar cane has also been tried and expensive works were erected for making sugar; but the production of this crop however is beset with obstacles as the newly fruits will not thrive to occur before the crop is harvested. The cultivation of rice seems to be very successful, the average net profit being about $150.00 per hectare. For this crop a large quantity of water is needed. It is estimated that for fields and hillsides upon which rice is grown are required to yield a water-power of during a period of 100 days, which is equivalent to a depth of water over the whole field of 5 feet. This no doubt dates is necessary to the principally to an excessive evaporation caused by the strong heat and dry atmosphere during the summer.

Corn is the principle crop. It produces about 25 bushels per acre. 10,000 acres planted one year yielded a net profit of $150,000.00, that is, the amount over the actual cost of production in the field.

PLATE VIII shows the location of the irrigable lands, and the means of working the lots.

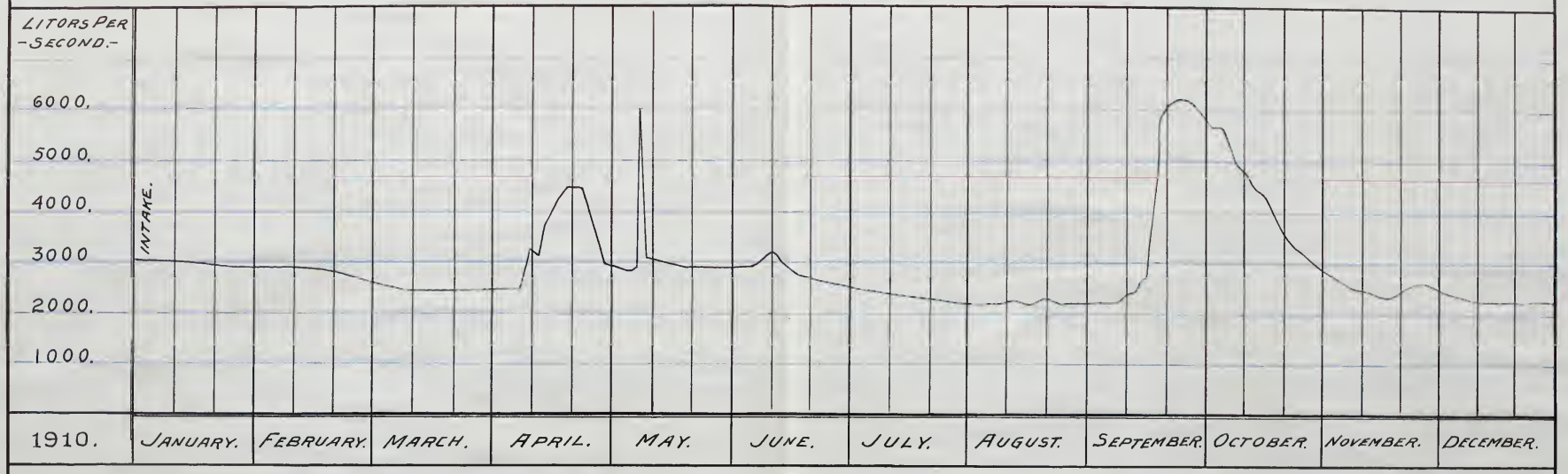
VALUE OF THE ENTERPRISE AS AN INVESTMENT. The enterprise can not be considered a failure, because it pays operating expenses and a small interest on the investment, and it also has a great prospective value. It has not however been as remunerative as it was generally hoped. Some of the causes which the investment had not produced better returns are:

1. The failure from a railroad making its way up the Orange-

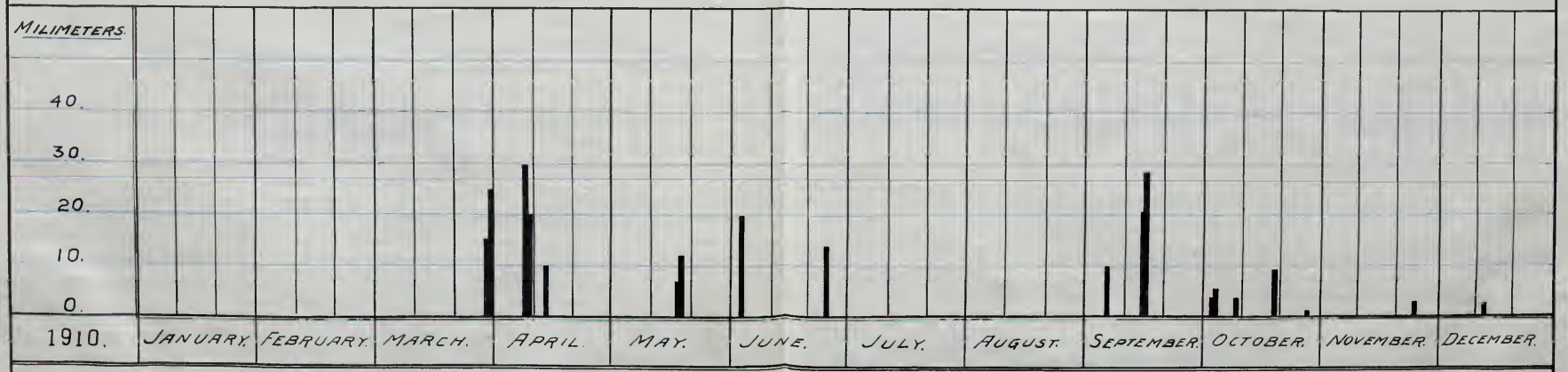
PLATE IX.

SAN DIEGO CANAL.

DIAGRAM OF FLOW IN CANAL DURING 1910.



PRECIPITATION AT SAN CARLOS FOR 1910.



port [illegible] extensive. A railway [illegible] project [illegible] to [illegible] Texas to Alpine -- on [illegible] Transcontinental Railway. It would [illegible] pass through the property and the transportation problem would be much [illegible] simplified.

7. The property is [illegible] and [illegible] gives it his personal attention. The direction and [illegible] is entirely in the hands of a [illegible], and [illegible] will have not much [illegible] fortune to [illegible] collection of his earnings.

8. The property is too large to be held under [illegible] management; [illegible] one man [illegible] cannot be efficiently conversant with all the necessary details.

9. The interest -- not [illegible] personal interest -- [illegible] unfavorable. They become dissatisfied and drift away and others must [illegible] account in [illegible] present expense. If a part of the estate were divided into comparatively small [illegible] to deal with a corresponding interest in [illegible] -- and sold to desirable settlers, there would be built up a community from [illegible] labor could be obtained for the cultivation of the [illegible] part of the property.

9. The gradual [illegible] of the normal rainfall and the consequent diminution of the flow in the canal. Right [illegible] the rainfall for 1910 at San Angelo, about 17in in the canal for the same year. From this cause [illegible] increased flow in the canal has to effect [illegible] dissatisfaction. For only ten days in September did the canal carry its full complement of water. At that time there was flowing in the first 2,000 cubic feet of water per second. Canals of great capacity and impounding reservoirs, should be built at first and additions made of the carrying plant [illegible] possible, as the need arises in the future. These reservoirs

should be located on ground above the Orkondo Arroyo. The canal would be short. While irrigation is carried on all the year, still in the winter comparatively little water is used; and the supply should be also improved. By promoting these objects in the construction of the property, there is no reason why it should not promise a satisfactory interest on the invest ent -- provided the precipitations do not fall much below that of last year.

F I N I S .

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